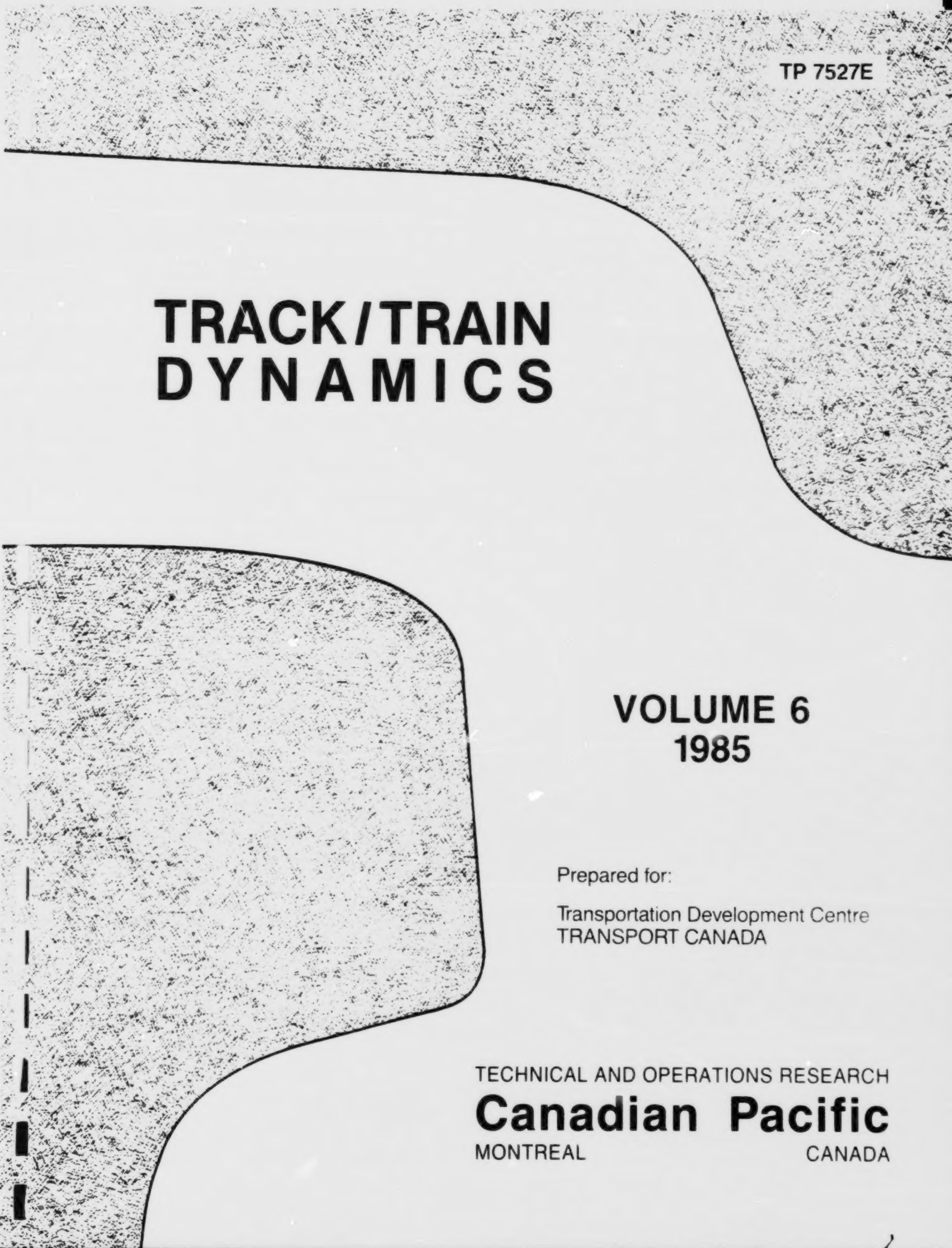

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VOLUME 6
1985

Prepared for:

Transportation Development Centre
TRANSPORT CANADA

TECHNICAL AND OPERATIONS RESEARCH
Canadian Pacific
MONTREAL CANADA

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17. Abstract

This final report is a collection of individual reports and project updates on research programs conducted under the cost-sharing agreement between Canadian Pacific Limited and the Transporation Development Centre during the period April 1985 to March 1986.

Research activites covered in this report include: field evaluation of Japanese Superrail, AWC-340 carbon rail and NKK-AHH rail; development of an acceptable welding cycle for an experimental head-hardened alloy rail produced by Algoma Steel; measurement of wheel/rail angles of attack on tangent track for various service conditions; evaluation of various types of side-bearings; strain measurements on concrete bridge ties; and, in-service evaluation of the PACT (slab track).

18. Key Words

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17. Résumé

Ce rapport final rassemble un certain nombre de rapports d'avancement et de mise à jour concernant les programmes de recherche conduits aux termes de l'accord sur le partage des frais conclu entre le Canadien Pacifique Ltée et le Centre de développement des transports, pour la période allant d'avril 1985 à mars 1986.

Les domaines de recherche concernés sont les suivants: évaluation en service du "Superrail" japonais, du AWC-340 et du rail NKK-AHH; mise au point d'un cycle thermique acceptable pour le soudage du rail expérimental à champignon durci par trempe réalisé par Algoma Steel; mesure de l'angle d'inscription dans les alignements, dans des conditions de service variables; évaluation de divers types de glissières; mesure des déformations dans les traverses en béton équipant les ponts-rails; évaluation en service de la plate-forme ferroviaire en béton.

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PREFACE

This report is one of a continuing series of such reports which are issued to present the results of various research programs conducted by the Research and Development Department of CP Rail, and related to Track/Train Dynamics.

The study of Track/Train Dynamics has been ongoing for a number of years with the principal objective being to improve our overall knowledge of the complex operating environment of the rail vehicle and track structure and the resulting stress placed upon these components. The acquisition of this knowledge has resulted in enhanced safety accompanied by a reduction in operating and maintenance costs.

The attached report describes the methodology, results and recommendations of a number of programs that were underway during the period April/85-March/86.

CP Rail again wishes to acknowledge the assistance contributed by many railway personnel and industry colleagues in carrying out these programs. In particular, we wish to acknowledge the contribution of cost shared financial support, which was provided by the Transportation Development Centre (Transport Canada) and which permitted our research efforts to be more extensive and vigorous than would have been otherwise possible.

R.A. Shea
General Manager,
Research and Development

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FIELD EVALUATION OF THE WEAR PERFORMANCE OF JAPANESE HEAD-HARDENED ALLOY RAIL (NSC SUPERRAIL)

K. Griffin
L. Feiter
H. Schrekinger

Research & Development
CP Rail
Report No. T-881-85
June, 1985

SUMMARY

Head-hardened alloy rail (Superrail) purchased from the Nippon Steel Corporation of Japan was installed, together with Algoma 1% Cr rail, in a series of short, sharp, reverse curves on the Pacific Region of CP Rail in late March, 1983. The wear performance of the Superrail was evaluated, in relation to Algoma 1% Cr rail, using data obtained with the rail profilometer developed by the Planning and Research Department, CP Ltd. Qualitative field observations were also periodically made to evaluate the relative susceptibilities of these two rail types to surface defect formation.

For both high and low rail positions in the fully developed sections of curves, Algoma 1% Cr rails consistently experienced far more wear than comparably located Japanese Superrails (based on last measurements collected in February, 1985). While the amount of wear experienced by these test rails was dependent on the severity of loading (eg. curvature, grade, etc.), the relative differences in wear experienced between comparable Cr and Superrail sections were consistent. For the various test sites and curvatures examined, high Cr rails experienced from 85 to 600, marginal to +150 and 20 to 125% more vertical, gauge face and total head wear, respectively, than similarly located Superrail. Corresponding low Cr rails experienced from 45 to 215 and 25 to 265% more vertical and total head wear, respectively, than comparable low Superrails. A comparison of relative condemning limits indicated that the wear life of the Superrail would range from 25 to +100% longer than corresponding Cr rails. In some cases, however, the service life of Cr rails was determined by surface defect formation, not wear.

Significant shelling damage was first noted on the running surface of Algoma 1% Cr rails on the low rail sections of fully developed curves after approximately 67 MGT. Corresponding Japanese Superrails, to date, exhibit only intermittent shelling on their top running surface. Low Algoma 1% Cr rail sections are also much more susceptible to plastic flow and the development of long-wavelength corrugations than corresponding Superrail sections. Japanese Superrails were initially (~27 MGT) susceptible to slight high rail gauge corner shelling. As of the last measurements in February, 1985 (~113.2 MGT) these shells had not progressed and are not significant.

The Japanese Superrail is markedly superior to both the Algoma 1% Cr rail and a previously examined Russian P-65 rail in its resistance to wear and surface defect formation. The practices of rail transposition and grinding, along with the use of continuous welded rail, will likely influence the applicability of this conclusion. These factors have not been rigorously considered in this report.

SOMMAIRE

La tenue à l'usure de deux rails, le "Superrail" à champignon durci par trempe fourni par la Nippon Steel Corporation of Japan et le rail Algoma 1 p. 100 Cr, a été comparée, après qu'ils eurent été installés sur une série de contre-courbes prononcées du réseau CP Rail, région du Pacifique, à la fin de mars 1983. L'étude comparative s'est fondée sur les données fournies par le profilomètre étudié par le Service de planification et de rech[illegible]e, CP Ltée. Des observations périodiques ont également été faites afin de déterminer la susceptibilité relative de ces deux rails aux avaries de surface.

Au milieu des courbes, le rail Algoma posé en files extérieure et intérieure a affiché de façon constante beaucoup plus d'usure que le Superrail japonais en position comparable (en se basant sur les données les plus récentes obtenues en février 1985). En admettant que l'usure des tronçons varie selon les efforts exercés: degré de courbure, pente, etc., il reste que les écarts constatés dans les deux cas se sont constamment vérifiés. Selon le site considéré et le degré de courbure, le rail Algoma en file extérieure a affiché des valeurs d'usure verticale, latérale et totale supérieures respectivement de 85 à 600 p. 100, de 0 à 150 p. 100 et de 20 à 125 p. 100, par rapport au "Superrail" en positions comparables. En file intérieure le rail Algoma affiché des valeurs d'usure verticale et totale supérieures de 45 à 215 p. 100 et de 25 à 265 p. 100 respectivement par rapport au "Superrail. Sur le plan du seuil de mise au rebut, l'analyse montre que le "Superrail" a une durée de vie utile de 25 à 100 p. 100 supérieure au rail Algoma correspondant. Dans certains cas, cependent, le retrait du rail Algoma a été motivé par la formation d'avaries de surface plutôt que par l'usure.

L'écaillage a commencé à devenir évident sur la surface de roulement du rail Algoma en file intérieure et au milieu des courbes en bout de 67 MTB, environ, le rail japonais ne montrant qu'un écaillage intermittent, en comparison. De plus, toujours en file intérieure, le rail Algoma s'est montré beaucoup plus susceptible à un écoulement plastique et à l'apparition d'usure ondulatoire à grande longueur d'onde que le rail japonais correspondant. Au début (27 MTB), ce dernier manifestait un léger écaillage du coin intérieur du rail extérieur mais, comme l'ont montré les résultats les plus récents enregistrés de février 1985 (113, 2 MTB), cette avarie n'avait pas progressé et demeurait négligeable.

Le rail japonais s'est montré décidément supérieur au rail Algoma de même qu'au rail P-65 de fabrication russe qui avait fait précédemment l'objet d'une étude comparative. Cette constatation vaut autant pour la résistance à l'usure que pour celle aux avaries de surface. Néanmoins, la permutation et le meulage des rails, ainsi que l'emploi des LRS, risquent de remettre en cause la validité de ces conclusions, ces facteurs n'ayant pas été pris en compte avec toute la rigueur voulue.

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1.0 INTRODUCTION

The recent trend towards higher speeds, larger trains and larger axle loads has placed increasingly severe demands upon rail steels. Rail life has markedly been shortened. Rail maintenance work, rail replacement and the accompanying interference to traffic have also become more frequent. These factors, together with the economic necessity for operating at maximum capacity and the high cost of rails in track, all support continuing efforts into the development and testing of new rail steel metallurgies.

As part of CP Rail's continuing program for the evaluation of new rail steel metallurgies, head-hardened alloy rail purchased from the Nippon Steel Corporation of Japan was installed in three test sites on the Pacific Region of CP Rail in late March, 1983. This rail, commonly referred to as Japanese Superrail, is 68 kg/m (136 lb/yd) and combines the two commercially accepted methods for improving the mechanical properties of rail steels -- selective alloying element additions (specifically Cr-Si with trace Nb) and heat-treatment (a slack quenching procedure is employed).

This report presents the results of in-service comparative wear testing of the Japanese Superrail in relation to Algoma 1% Chrome rail, along with qualitative field observations on the relative susceptibilities of these two rail types to surface defect formation. Descriptions of the test locations and method of data acquisition and analysis are included. General comparisons are also made between the in-service performance of the Superrail and a previously tested P-65 Russian rail (see Reference 1), each in relation to the standard Algoma 1% Cr rail and for similar tonnage passing levels.

2.0 TEST SITES AND MEASUREMENT POINTS

The three test sites on the Pacific Region that were initially selected for evaluation of the Japanese Superrail are:

Site #1 - Mile 22.9, Cascade Subdivision
Site #2 - Mile 102.1, Thompson Subdivision
Site #3 - Mile 113.0, Thompson Subdivision

Details of the rail materials (see Table 1) and track characteristics covered in this study are summarized below:

Table 1

Comparison of Physical and Metallurgical Properties of Algoma 1% Chrome and Japanese Superrail

Characteristics	Algoma 1% Cr (2)	Japanese Superrail (3)
Type	1.15% Cr Alloy	Head-Hardened Cr/Si/Nb Alloy
Section	AREA 136 lb/yd	AREA 136 lb/yd*
Properties:		
0.2% YS (ksi)	95	130
UTS (ksi)	150	192
Elongation (%)	9	19
Reduction in Area (%)	17	50
Head-Hardness	320	380
Steelmaking	BOF, Si-Killed	BOF, Si-Killed
Microstructure	fully pearlitic	fully pearlitic

*As reported initially by the Nippon Steel Corporation

Track

Geometry: High and low rails of fully developed sections of curves ranging in curvature from 3.50 to 9.00 degrees and in length from 250 to 800 ft. Spirals and tangent sections of various lengths, up to 800 ft.

Welding Practice: Continuously flash butt welded track. Joint bars connect different rail sections.

Ties: Wood.

Superelevation: From 0.00 to 3.75 in. for tangent and spiral sections and 2.25 to 4.50 in. for fully developed sections of curves.

Grade: Site #1: -0.60% to -1.00% (westbound)
Site #2: +1.30% to -0.10% (westbound)
Site #3: -0.70% to +0.40% (westbound)

Lubrication: Molybdenum disulphide based grease.

Axle Load: Approximately 32.5 tons maximum.

Track Speed: 10 mph to 30 mph.

Annual Traffic: Approximately 60 million gross tons (MGT).

In April 1983, the curvature, superelevation and track gauge at the three Superrail test sites were first measured and points of wear measurement selected. In July 1983, the track in test site #1 was significantly altered (i.e. curvature and superelevation reduced, spirals lengthened) and the Planning and Research Department discontinued wear measurements on this site. Insufficient tonnage (~18 MGT) passed over test site #1 prior to this maintenance to support a viable wear test; this site and its wear data are not examined in this report. Subsequent track measurements were made in September '83, May '84, September '84 and again in February '85 to confirm that there were no significant changes in the remaining test sites #2 and #3 — shown schematically in Figures 1 and 2, respectively. In the period March/May 1985, the rails in test site #3 were transposed and ground to counter extreme shelling and gauge face wear -- particularly with the Algoma 1% Cr rail sections. Wear measurements were then discontinued on this site, but sufficient tonnage had passed over test site #3 to evaluate the performance of the Japanese Superrail relative to the Algoma 1% Cr rail. Final track measurements on test site #2 are tentatively scheduled for July 1985. Test sites #2 and #3 experienced the same general traffic, approximately 113.2 MGT, up to the end of February 1985. Information on the traffic passing over these sites was supplied by the Engineering Department, CP Rail.

A total of 44 relative wear measurement points were selected on the Japanese Superrail test sites #2 and #3, located in groups of four about the eleven change-over points from one rail type to the other (see Figures 1 and 2). Forty of these measurement points are located on the fully developed sections of curves; the remaining four are on a spiral in test site #3. All measurement points are numbered in Figures 1 and 2, and later listed in Tables 2 and 3. Possible joint effects required that the measurement points be located several feet from the joint; six feet were allowed for in the present test.

3.0 DATA COLLECTION AND ANALYSIS

All profile/wear data was collected with the rail profilometer (see Reference 4) developed by the Planning and Research Department, CP Ltd., and processed on the microcomputer in the department.

At all three test sites, new profile measurements were first taken at the selected points in April 1983, within several weeks of the installation of the test rail. These new profiles, coupled with future wear measurements, allow for a relative comparison of the two rail types based on absolute and/or cumulative wear. Subsequent profile measurements were taken at the remaining test sites #2 and #3 in September '83, May '84, September '84 and again in February '85. An additional series of profile measurements are scheduled to be taken at test site #2 in July 1985. At these times, qualitative field observations of surface defects exhibited by the two rail types were/will be made.

For each profile comparison, three indices of relative wear are reported. These are: vertical head loss, loss at the gauge face and head area reduction. The vertical and gauge face losses are calculated in accordance with standard practice (see Reference 5), as shown in Figure 3. The area calculations will consider as lost the material which has been removed from the rail head and material which has flowed outside the original profile (eg. the "lip" often found on rails in tangent track and on the field side of low rails in curves). The resolution limit of the profilometer for vertical and gauge face wear is 0.004 in. (0.1mm) and approximately 0.016 sq. in. (10mm^2) for total head wear. For profile matching purposes, a difference of 0.008 in. (0.2mm) has been specified as the minimum difference required to constitute significant vertical and/or gauge face wear; 0.031 sq. in. ($20mm^2$) has been specified for total head wear comparisons.

For each of test sites #2 and #3, the variation of wear between similarly positioned high and low rails of different type (i.e. at each rail change-over point) was studied. Individual measurement points from different change-over points were not directly compared; test sites #2 and #3, as well as the individual change-over points within each test site, experienced different wear due to unique traffic levels, track alignment, dynamic loading conditions, braking practices and lubrication.

Both the Algoma 1% Cr and the Japanese Superrail are 136 lb/yd rail sections; therefore, their wear performance may be directly compared. Accordingly, characteristic wear trends will be based, and reported, on the amount of wear experienced by these different rail types. While it is recognized that these rails are of similar section size, they are of different section. It was initially reported that the Superrail was rolled to the same AREA-136 section as the Algoma 1% Cr rail (see Figure 4). Subsequent examination revealed that this was not the case. A detailed schematic is not available but the Japanese Superrail has a flatter rail head running surface, more gradual upper-gauge face and upper-field side corners, and sharper head/web and web/base fillets. These differences affect wheel/rail contact geometry, load distribution and resulting rail (and wheel) wear. The condemning limits of the two rail types (see Figure 5) were considered in the analysis of the wear data.

4.0 RESULTS AND CONCLUSIONS

The two remaining Japanese Superrail test sites differ in the magnitude of wear, and severity of surface defects, experienced by similar rail types and rail locations. This is expected since each site is uniquely characterized by different traffic levels, track alignment, dynamic loading conditions, braking practices and lubrication. Specifically, test site #3 consists of a series of 8-8.5 degree reverse curves and is characterized by a necessarily harsh braking practice because of its large negative grade (-0.7% to 0.0%, westbound). Alternately, the curvatures in test site #2 vary from 3.5 degrees to 8.5 degrees and a quite mild braking practice is employed because of its decreasing positive grade (+1.3% to -0.1%, westbound). For each remaining test site, there were consistent wear and surface damage differences on similarly positioned high and low rails of different type. Data collected from different sites have not been directly compared.

As of February 1985, sufficient tonnage had passed over test sites #2 and #3 for an absolute comparison of the two rail types on the basis of cumulative wear and resistance to surface defect formation (for the given test conditions of limited maintenance, with no rail grinding or transposition) -- these comparisons are reported here.

4.1 Wear Analysis

The wear versus tonnage variations for all of the measurement points in the remaining test sites #2 and #3 are listed in Tables 2 and 3, respectively. A large number of matched profiles and cumulative wear plots were produced to analyze this data. While it is not feasible to include all of these in this report, representative samples are presented (see Appendix A).

For each of test sites #2 and #3, high and low Algoma 1% Cr rails consistently experienced more wear than comparably located high and low Japanese Superrails. Further, while test site #3 rails generally experienced more wear than those from test site #2, the relative differences in wear experienced between comparable Cr and Superrail sections were consistent. Accordingly, test sites #2 and #3 each indicate a similar degree of superiority of the Japanese Superrail over the Algoma 1% Cr rail. As of the last profile measurements taken in February, 1985 (~113.2 MGT), the test rails were exhibiting relatively stable wear patterns.

Specifically for test site #2, high Cr rails in the fully developed section of curves experienced from 85 to 175, 60 to +150 and 20 to 90% more vertical, gauge face and total head wear, respectively, than similarly positioned Japanese Superrail (based on last measurements taken in February, 1985). Corresponding low Cr rails exhibited 45 to 200 and 25 to 200% more vertical and total head wear, respectively, than comparable low Superrails. For similar February, 1985 profile measurements, high Cr rails in test site #3 experienced from 145 to 600, marginal to 145 and 20 to 125% more vertical, gauge face and total head wear, respectively, than similarly located high Superrails. Low Cr rails here exhibited from 80 to 215 and 65 to 265% more vertical and total head wear, respectively, than comparable Japanese Superrail.

It was initially noted in July, 1984 (see Reference 6) that both high and low Algoma 1% Cr rails were wearing to a flatter running surface profile, similar to that characteristic of new Japanese Superrail. As a combined result of their different metallurgies and initial geometries, Cr rails experienced a much greater initial rate of vertical head wear than corresponding Superrails. This divergence in vertical wear rates was expected to decrease or level out as the two worn rail geometries approached one another, and this has occurred. The flatter initial running surface profile of the Superrail, relative to the standard AREA 136-RE profile, warrants further examination.

The above results illustrate the relative differences in the amounts of wear experienced by similarly located Algoma 1% Cr and Japanese Superrails. A comparison of relative condemning limits was performed (see Appendix B) and indicated that, under the given test conditions, the wear life of the Superrail would range from 25 to +100% longer than corresponding Cr rails. In some cases, however, the service life of Cr rails was determined by surface defect formation, not wear (see Section 4.2).

Contrary to the wearing differences noted above, previous test work (see Reference 1) has shown that Russian P-65 rails exhibit only similar wear resistance to Algoma 1% Cr rails when located in the high rail position in the fully developed section of a curve. In the low rail position, P-65 rails were less resistant to wear than Algoma 1% Cr rails. The Japanese Superrail is markedly superior to both the P-65 and Algoma 1% Cr rail in its resistance to wear.

4.2 Surface Defects

Qualitative differences in surface character between the Japanese Superrail and the Algoma 1% Cr rail were first noticeable, for both high and low rails in the fully developed sections of curves, in May 1984 (after approximately 67 MGT). These differences have continued to the present and are consistent for each of test sites #2 and #3. The degree of damage exhibited by test site #3 rails is much greater than for corresponding rail types and locations in test site #2, for similar tonnage passing levels — this results from the higher curvatures, negative grade and severe braking practice which most distinguishes test site #3 from test site #2.

For each of test sites #2 and #3, the high rail gauge corner shelling that was first noted on the Japanese Superrail in May 1984 has not significantly progressed since this date. Other railroads (see References 7 and 8) have also observed this initial high rail gauge corner shelling of the Japanese Superrail, with no subsequent extension of the problem, in their rail evaluation programs. It is presently felt that this shelling does not arise from any basic weakness of the Superrail metallurgy; rather, it likely results from the rest of the line being worn, so the wheel flanges had worn to match the "average" Algoma Cr worn rail profile and had a mismatch with the different, relatively new, Superrail profile — resulting in excessive contact stresses on the sharper gauge corner of high Superrails. Along with wheel/rail geometry, the high strength of the Japanese Superrail may have actually promoted initial shell formation by not allowing plastic deformation to occur to any significant depth into the railhead, thereby generating high lattice strain. These shells are readily removed by grinding. As well, a small change in rail geometry could shift the load away from the high rail gauge corner and towards the tread contact area. The early formation of these defects, coupled with the fact that they did not significantly progress after forming, reflects the high strength of the Japanese Superrail and shows that this is primarily a geometric, not a material, problem.

High rail gauge corner shelling of the Algoma 1% Cr rail was also first observed in May 1984 (~67 MGT). This shelling damage has increased with increasing traffic, however, and is presently more severe than that damage exhibited by corresponding Japanese Superrails. Grinding would also remedy the Algoma 1% Cr high rail gauge corner shelling problem; however, the Cr rail geometry would necessitate a more extensive grinding operation (and therefore more material loss and expense) than that required for the Japanese Superrail. The early formation of these shells is due to severe service loading and an improper initial rail geometry; their continued growth reflects the lower strength of the Cr metallurgy relative to that of the Superrail. Further to the surface damage noted above, high Algoma 1% Cr rails exhibit greater plastic flow than corresponding high Japanese Superrails (see Figures A1 and A2).

Consistent with the high rail case, low Algoma 1% Cr rails are less resistant to plastic flow than corresponding low Japanese Superrails — this is reflected by the larger plastic flow lips found on both sides of the Cr railhead, relative to the Superrail (see Figures A3 and A4). Further, Algoma 1% Cr rails consistently exhibit significant shelling on the low rail running surface in fully developed curve sections. Conversely, low Japanese Superrails exhibit, at most, intermittent shelling defects on the low rail running surface. Another example of the lower resistance to contact fatigue and plastic flow of the low Cr rails are the corrugations observed in each of the remaining test sites #2 and #3. These corrugations were most severe in test site #3 (as of February 1985, wavelength = 8-12", amplitude = 0.040-0.060"). Low Japanese Superrails did not exhibit corrugations.

The lower yield strength of the Algoma 1% Cr rail makes it more susceptible to excessive plastic deformation of the rail running surface due to shear, which gives rise to the initiation and propogation of surface and sub-surface rolling contact fatigue cracks. Such sub-surface cracks re-distribute contact stresses in a manner conducive to accelerated plastic flow and, therefore, accelerated fatigue crack formation — and so on. The lower shear strength of the Cr rail makes it more susceptible to flow, the formation of a shallow deformed/sheared surface layer, and resulting shells and corrugations.

In general, the severity of surface damage experienced by both high and low rails increased with increasing curvature.

General track maintenance, such as rail transposition and grinding, is performed to eliminate hazardous conditions and to prolong rail life. Grinding, in particular, is used to eliminate surface defects which may constitute operating hazards or which, in time, could be life-limiting. As the effects of different types of corrective maintenance can be difficult to fully account for in a rail evaluation program, the present Japanese Superrail trials did not include any such maintenance. It is recognized that service-life estimates determined here by surface defect formation for both the Japanese Superrail and the Algoma 1% Cr rail will accordingly be conservative, but are still valid on a comparative basis between the two test rail types. A more comprehensive rail evaluation program (see Appendix C) would attempt to include the effects of track maintenance.

In the period March/May 1985, rails in test site #3 were transposed to counter extreme low rail shelling and high rail gauge face wear -- particularly with Algoma 1% Cr rail sections. These rails were subsequently ground in late May, 1985. Field personnel estimated that if the Algoma 1% Cr rails, and by necessity the paired Japanese Superrails, had not been so maintained, all test site #3 rails would have had to been scrapped in 3-4 months. The severe surface damage (and wear) initially experienced by the Cr rails produced high impact loading on both the Superrail and Algoma 1% Cr rails, accelerating the subsequent surface damage experienced by each rail type. Under the given test and loading conditions for test site #3, it is estimated that the Cr rails alone would have had to been scrapped after less than 150 MGT for excessive surface damage. Corresponding Japanese Superrails, alone, would likely not have had to been scrapped for surface defects — rather, for wear (see Section 4.1).

Under the less severe loading conditions in test site #2, it was not absolutely necessary for either test rail type to be ground or transposed as of February 1985 (~113.2 MGT). At this time, each rail type exhibited stable wear rates and rail life projections were made (see Section 4.1). The Algoma 1% Cr rails here exhibit some surface damage and, under normal maintenance guidelines, would have received a light, single-pass, grind after 50-100 MGT. Corresponding Japanese Superrails have only marginal surface damage. It is estimated that it would not be absolutely necessary here to grind/transpose either rail type until +200 MGT. The Engineering Department of CP Rail plans to continue monitoring rails from each of test sites #2 and #3 until they are condemned; their program will involve normal track maintenance, as required, and will attempt to more realistically compare the economics of the two test rail types.

In a similar rail evaluation program completed in mid-1984, Russian P-65 rails experienced far more low rail shelling than did corresponding Algoma 1% Cr rails. Pronounced shelling was observed as early as 65 MGT when qualitative field observations were first made. In that program, neither the P-65 nor the Algoma 1% Cr rails exhibited noticeable high rail gauge corner shelling. The Japanese Superrail is markedly superior to both the P-65 and Algoma 1% Cr rail in its resistance to plastic flow, corrugations, and high and low rail shelling.

5.0 RECOMMENDATIONS

- On the basis of in-service performance, the Japanese Superrail (or its equivalent) should replace the Algoma Cr premium rail in high tonnage +3 degree curves.

- Future rail evaluation programs should incorporate normal rail maintenance, thereby allowing for a "bottom-line" economic assessment of a rail steel.

- Research should be undertaken to examine the effects of a pre-worn railhead profile, typical to CP heavy-haul service, on rail/wheel wear.

- The measurement of Algoma 1% Cr and Japanese Superrail profiles at test site #2 should be continued to confirm the stability of the reported wear versus tonnage patterns.

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Table 2

Cumulative Wear Data for Test Site #2

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
1 (3.5 degree)	1-HCr	Vertical (in.)	0	0.016	0.031	0.028	0.040
		Gauge Face (in.)	0	0	0.039	0.074	0.112
		Total Area (sq. in.)	0	0.022	0.083	0.128	0.181
	2-LCr	Vertical (in.)	0	0.008	0.024	0.035	0.052
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.016	0.033	0.068	0.091
	3-HJ	Vertical (in.)	0	0	0	0.012	0.016
		Gauge Face (in.)	0	0	0	0.020	0.044
		Total Area (sq. in.)	0	0.007	0.027	0.086	0.116
	4-LJ	Vertical (in.)	0	0.016	0.016	0.028	0.036
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.019	0.024	0.049	0.071
2 (6.5 degree)	5-LJ	Vertical (in.)	0	0.012	0.031	0.039	0.056
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.031	0.079	0.096	0.125
	6-HJ	Vertical (in.)	0	0	0.028	0.024	0.028
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.011	0.066	0.073	0.105
	7-LCr	Vertical (in.)	0	0.028	0.087	0.110	0.168
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.051	0.170	0.214	0.345
	8-HCr	Vertical (in.)	0	0.024	0.039	0.055	0.068
		Gauge Face (in.)	0	0.020	0.020	0.039	0.084
		Total Area (sq. in.)	0	0.045	0.076	0.124	0.196

Table 2

Cumulative Wear Data for Test Site #2 (Contd.)

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
3 (8.5 degree)	9-HCr	Vertical (in.)	0	0.024	0.059	0.067	0.088
		Gauge Face (in.)	0	0	0.059	0.083	0.136
		Total Area (sq. in.)	0	0.049	0.158	0.202	0.307
	10-LCr	Vertical (in.)	0	0.039	0.071	0.110	0.160
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.070	0.139	0.214	0.323
	11-HJ	Vertical (in.)	0	0	0.016	0.020	0.032
		Gauge Face (in.)	0	0	0	0.028	0.056
		Total Area (sq. in.)	0	0.021	0.071	0.104	0.159
	12-LJ	Vertical (in.)	0	0.024	0.039	0.043	0.072
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.045	0.083	0.090	0.146
4 (4.5 degree)	13-LJ	Vertical (in.)	0	0.008	0.020	0.020	0.036
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.006	0.030	0.037	0.063
	14-HJ	Vertical (in.)	0	0.008	0.012	0.016	0.024
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.027	0.044	0.065	0.103
	15-LCr	Vertical (in.)	0	0.024	0.055	0.063	0.080
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.082	0.088	0.099	0.146
	16-HCr	Vertical (in.)	0	0.008	0.031	0.031	0.044
		Gauge Face (in.)	0	0	0	0.020	0.036
		Total Area (sq. in.)	0	0.015	0.055	0.073	0.120

Table 2

Cumulative Wear Data for Test Site #2 (Contd.)

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
5 (6.5 degree)	17-LCr	Vertical (in.)	0	0.028	0.094	0.118	0.160
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.033	0.160	0.224	0.311
	18-HCr	Vertical (in.)	0	0.020	0.047	0.055	0.072
		Gauge Face (in.)	0	0.024	0.047	0.083	0.148
		Total Area (sq. in.)	0	0.059	0.129	0.171	0.270
	19-LJ	Vertical (in.)	0	0.016	0.043	0.047	0.060
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.018	0.078	0.082	0.104
	20-HJ	Vertical (in.)	0	0	0.020	0.055	0.058
		Gauge Face (in.)	0	0	0.020	0.055	0.108
		Total Area (sq. in.)	0	0.019	0.079	0.126	0.178

*The following abbreviations designate the rail position and type particular to each measurement point:

HCr/LCr - Algoma 1% Cr rail on high/low rail of curve
HJ/LJ - Japanese Superrail on high/low rail of curve

Table 3

Cumulative Wear Data for Test Site #3

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
1 (8.5 degree)	1-LCr	Vertical (in.)	0	0.020	0.083	0.130	0.176
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.029	0.146	0.234	0.324
	2-HCr	Vertical (in.)	0	0.024	0.079	0.110	0.152
		Gauge Face (in.)	0	0.024	0.193	0.299	0.412
		Total Area (sq. in.)	0	0.050	0.295	0.490	0.740
	3-LJ	Vertical (in.)	0	0.016	0.039	0.047	0.056
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.046	0.068	0.086	0.089
	4-HJ	Vertical (in.)	0	0.008	0.028	0.035	0.052
		Gauge Face (in.)	0	0.024	0.126	0.165	0.240
		Total Area (sq. in.)	0	0.065	0.197	0.249	0.388
2 (8 degree)	5-HJ	Vertical (in.)	0	0.008	0.020	0.028	0.044
		Gauge Face (in.)	0	0	0.039	0.071	0.092
		Total Area (sq. in.)	0	0.020	0.113	0.163	0.212
	6-LJ	Vertical (in.)	0	0.028	0.039	0.043	0.052
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.043	0.061	0.083	0.088
	7-HCr	Vertical (in.)	0	0.031	0.067	0.098	0.140
		Gauge Face (in.)	0	0	0.079	0.114	0.164
		Total Area (sq. in.)	0	0.052	0.182	0.290	0.438
	8-LCr	Vertical (in.)	0	0.024	0.075	0.106	0.144
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.027	0.112	0.179	0.265

Table 3

Cumulative Wear Data for Test Site #3 (Contd.)

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
3 (8.5 degree)	9-LCr	Vertical (in.)	0	0.020	0.051	0.075	0.100
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.023	0.079	0.127	0.174
	10-HCr	Vertical (in.)	0	0.024	0.071	0.106	0.188
		Gauge Face (in.)	0	0.024	0.193	0.268	0.336
		Total Area (sq. in.)	0	0.054	0.290	0.456	0.733
	11-LJ	Vertical (in.)	0	0.016	0.039	0.043	0.056
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.036	0.072	0.083	0.098
	12-HJ	Vertical (in.)	0	0.012	0.024	0.035	0.052
		Gauge Face (in.)	0	0	0.118	0.193	0.264
		Total Area (sq. in.)	0	0.026	0.159	0.261	0.379
4 (8.5 degree)	13-HJ	Vertical (in.)	0	0.008	0.020	0.035	0.044
		Gauge Face (in.)	0	0	0.079	0.130	0.164
		Total Area (sq. in.)	0	0.026	0.140	0.219	0.272
	14-LJ	Vertical (in.)	0	0.016	0.031	0.043	0.048
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.018	0.060	0.077	0.080
	15-HCr	Vertical (in.)	0	0.020	0.075	0.114	0.144
		Gauge Face (in.)	0	0	0.118	0.181	0.228
		Total Area (sq. in.)	0	0.042	0.287	0.386	0.507
	16-LCr	Vertical (in.)	0	0.031	0.098	0.122	0.144
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.043	0.158	0.220	0.253

Table 3

Cumulative Wear Data for Test Site #3 (Contd.)

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
5 (8 degree)	17-LCr	Vertical (in.)	0	0.012	0.047	0.067	0.084
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.025	0.083	0.127	0.148
	18-HCr	Vertical (in.)	0	0.028	0.075	0.098	0.108
		Gauge Face (in.)	0	0	0.126	0.142	0.204
		Total Area (sq. in.)	0	0.045	0.237	0.298	0.376
	19-LJ	Vertical (in.)	0	0.012	0.028	0.024	0.028
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.024	0.059	0.060	0.065
	20-HJ	Vertical (in.)	0	0.012	0.028	0.028	0.044
		Gauge Face (in.)	0	0	0.098	0.138	0.212
		Total Area (sq. in.)	0	0.025	0.146	0.197	0.309
6 (Spiral into 8 degree curve)	21-LJ	Vertical (in.)	0	0.008	0.012	0.012	0.020
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.027	0.036	0.035	0.047
	22-HJ	Vertical (in.)	0	0.008	0.012	0.016	0.008
		Gauge Face (in.)	0	0	0	0	0.036
		Total Area (sq. in.)	0	0.016	0.050	0.067	0.078
	23-LCr	Vertical (in.)	0	0.012	0.039	0.043	0.048
		Gauge Face (in.)	0	0	0	0	0
		Total Area (sq. in.)	0	0.012	0.055	0.066	0.077

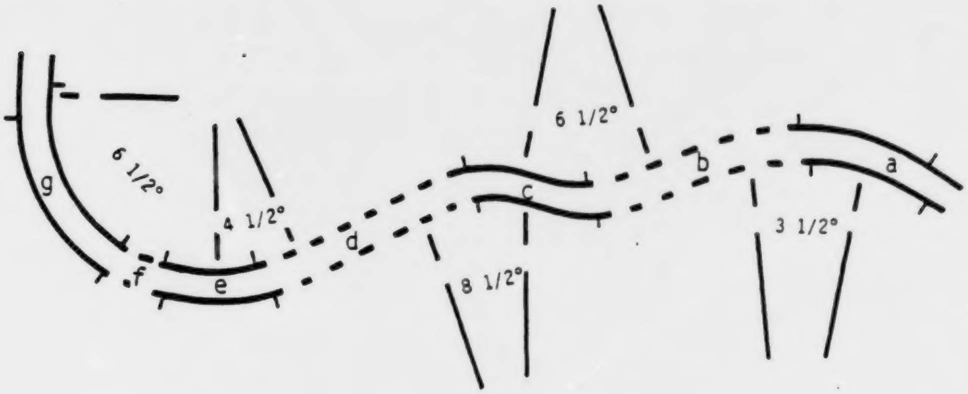
Table 3

Cumulative Wear Data for Test Site #3 (Contd.)

Change-Over and Degree	Measurement Point and Description*	Wear Indices	Cumulative Tonnage (MGT)				
			0 (Reference)	27.4	67.1	88.2	113.2
	24-HCr	Vertical (in.)	0	0.016	0.043	0.051	0.056
		Gauge Face (in.)	0	0	0.035	0.055	0.088
		Total Area (sq. in.)	0	0.017	0.083	0.116	0.176

*The following abbreviations designate the rail position and type particular to each measurement point:

HCr/LCr = Algoma 1% Cr rail on high/low rail of curve
HJ/LJ = Japanese Superrail on high/low rail of curve



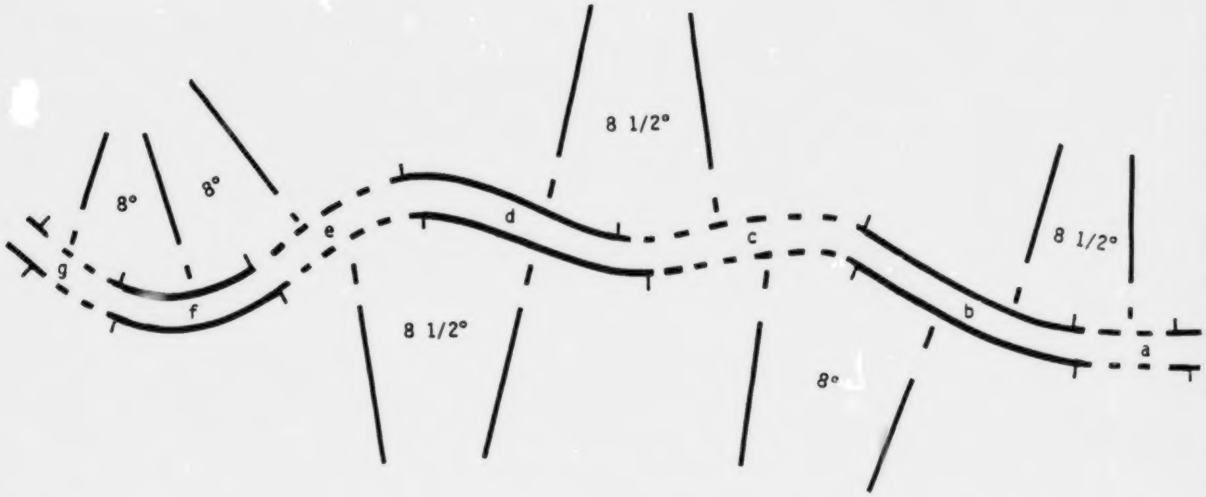
Mile 102.1 to 103.1,
Thompson Subdivision

Lubricators:
  north rail - MP 93.3 & 105.1
  south rail - MP 102.3

Japanese Superrail ------
Algoma 1% Cr Rail ______

Mark	Jap. Superrail North	Jap. Superrail South	Algoma Cr North	Algoma Cr South	Change-Over and Measurement Pts
a			555'	558'	
					1, 1-4
b	956'	955'			
					2, 5-8
c			873'	872'	
					3, 9-12
d	1052'	1053'			
					4, 13-16
e			1059'	1029'	
					5, 17-20
f	647'	679'			
					------
g			834'	624'	

Figure 1: Site #2: Track Layout with Curvatures and Location of Change-Over/Measurement Points



Mile 113.0 to 114.0
Thompson Subdivision

Lubricators:
north rail - MP 113.9
south rail - MP 113.9

Japanese Superrail ——

Algoma 1% Cr Rail - - -

Mark	Jap. Superrail		Algoma Cr		Change-Over and Measurement Pts.
	North	South	North	South	
a			286'	294'	1, 1-4
b	696'	605'			2, 5-8
c			795'	778'	3, 9-12
d	924'	925'			4, 13-16
e			970'	967'	5, 17-20
f	655'	652'			6, 21-24
g			333'	340'	

Figure 2: Site #3 -- Track Layout with Curvatures and Location of Change-Over/Measurement Points

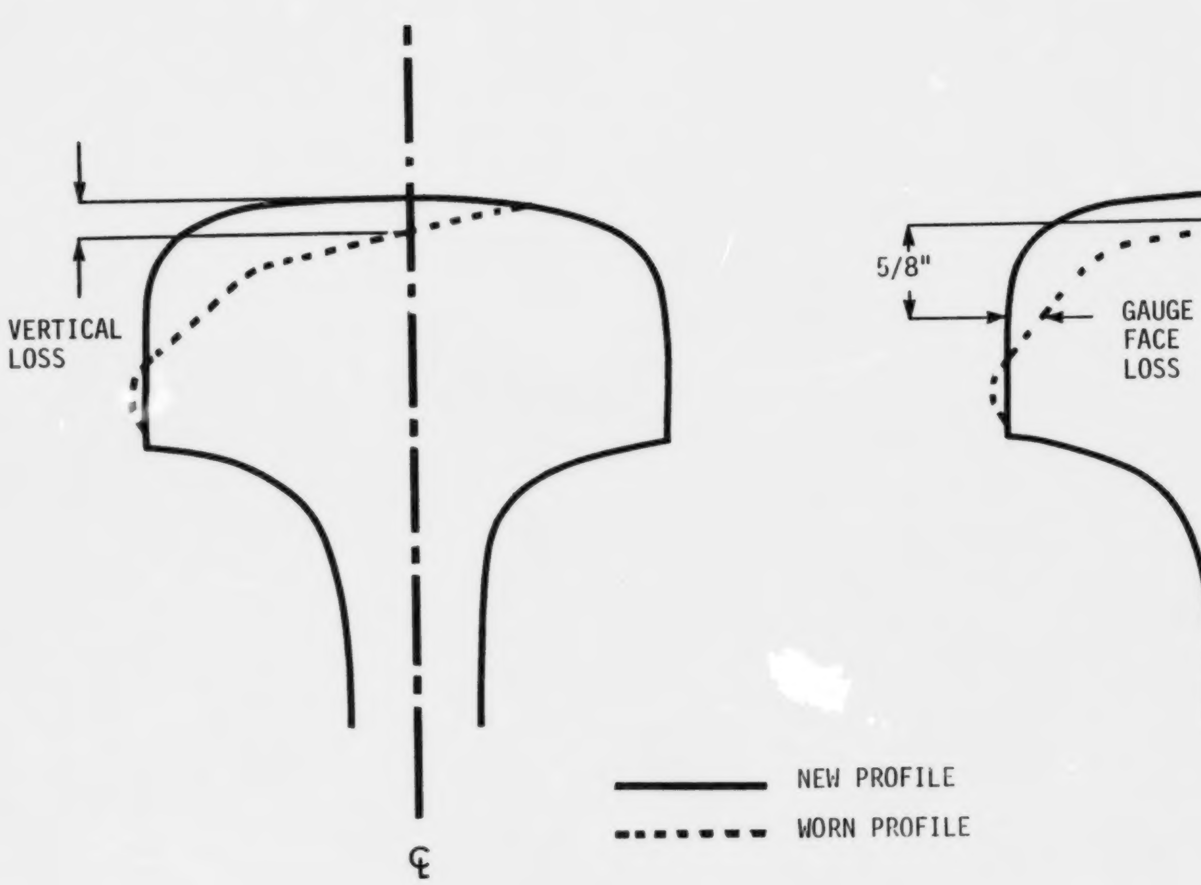
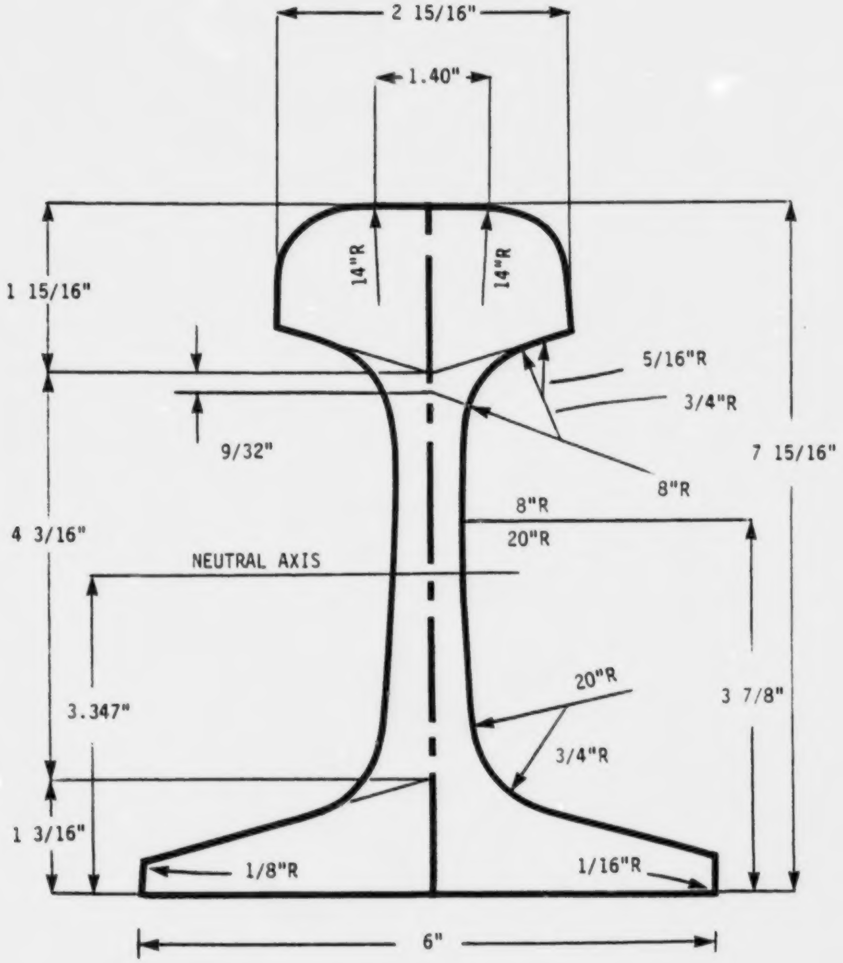

VERTICAL
LOSS
5/8"
GAUGE
FACE
LOSS
NEW PROFILE
WORN PROFILE
℄
℄

Figure 3: Definition of Vertical and Gauge Face Losses


2 15/16"
1.40"
14"R
14"R
1 15/16"
5/16"R
3/4"R
9/32"
8"R
7 15/16"
8"R
20"R
4 3/16"
NEUTRAL AXIS
20"R
3 7/8"
3.347"
3/4"R
1 3/16"
1/8"R
1/16"R
6"

Algoma 1% Cr Rail, AREA 136-RE

Figure 4: Algoma 1% Cr, AREA 136-RE Section

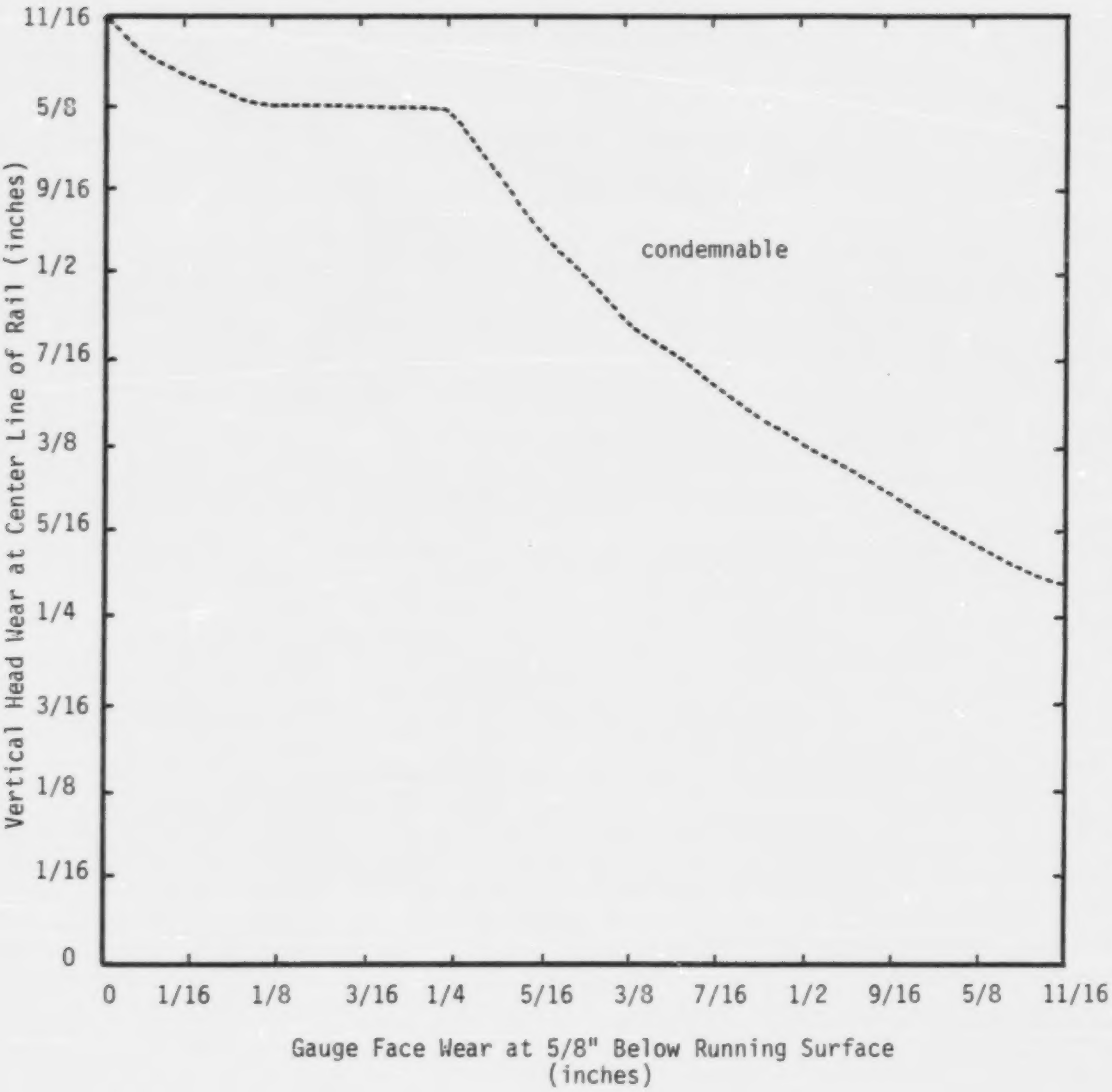


Figure 5: Maximum Rail Wear Limits: 136 RE Section

APPENDIX A

REPRESENTATIVE MATCHED PROFILES AND CUMULATIVE WEAR PLOTS

Figures A1-4 illustrate the matching procedure employed for high Cr, high Superrail, low Cr and low Superrail profile comparisons, respectively. In each case the final wear measurement taken at the given measurement point is matched against the original reference profile for that point, both of which are identified, and areas of plastic flow are noted. When material has flowed outside the original profile, it has been considered lost for profile comparison purposes. Figures A5-19 and A20-37 depict those generally consistent wearing trends presented in Tables 2 and 3, respectively. Table A1 provides the location of each measurement point presented in Figures A1-37, as given in either of Figures 1 or 2. Finally, Figures A38-39 summarize the percentage reduction in wear achieved by the Japanese Superrail, in relation to the standard Algoma 1% Cr rail, based on final cumulative wear profile comparisons of the two rail types taken from the remaining test sites #2 and #3, respectively. The "negative increases" in vertical head wear illustrated in Figures A5, A8, A32 and A35, and in total head wear as illustrated in Figure A37, lie within the resolution limits of the rail profilometer and are not significant.

Table A1

Location of Measurement Points

Figure No.	Applicable Test Site, Measurement Point(s) and Description	Figure Providing Location of Measurement Point in Relevant Test Site
A1	3, 2, high Cr	2
A2	3, 4, high Superrail	2
A3	3, 1, low Cr	2
A4	3, 3, low Superrail	2

Table A1 (Contd.)

Location of Measurement Points

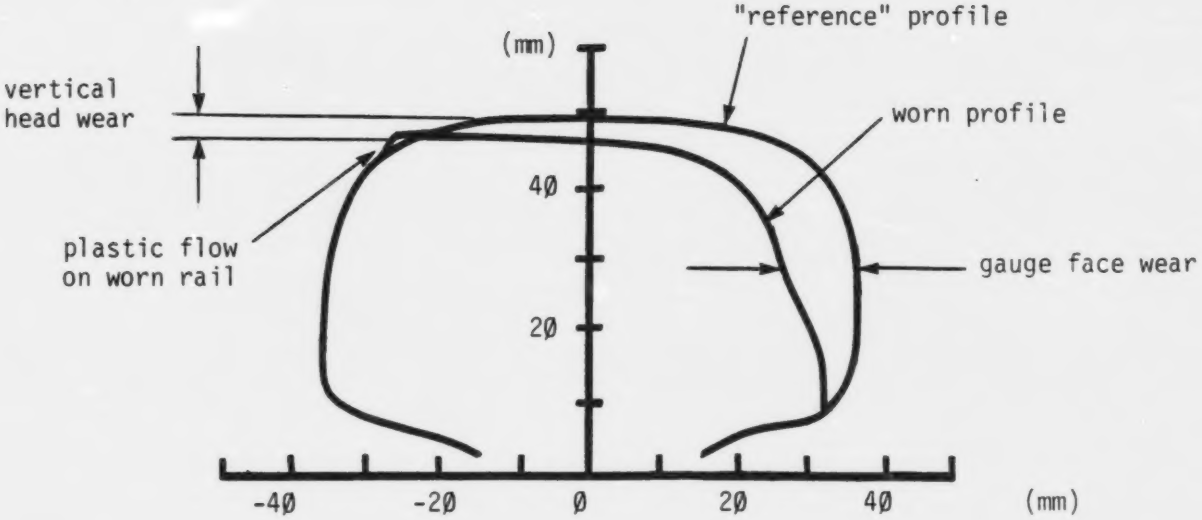
Figure No.	Applicable Test Site, Measurement Point(s) and Description	Figure Providing Location of Measurement Point in Relevant Test Site
A5-7	2, 1, high Cr	1
	2, 2, low Cr	1
	2, 3, high Superrail	1
	2, 4, low Superrail	1
A8-10	2, 5, low Superrail	1
	2, 6, high Superrail	1
	2, 7, low Cr	1
	2, 8, high Cr	1
A11-13	2, 9, high Cr	1
	2, 10, low Cr	1
	2, 11, high Superrail	1
	2, 12, low Superrail	1
A14-16	2, 13, low Superrail	1
	2, 14, high Superrail	1
	2, 15, low Cr	1
	2, 16, high Cr	1
A17-19	2, 17, low Cr	1
	2, 18, high Cr	1
	2, 19, low Superrail	1
	2, 20, high Superrail	1
A20-22	3, 1, low Cr	2
	3, 2, high Cr	2
	3, 3, low Superrail	2
	3, 4, high Superrail	2
A23-25	3, 5, high Superrail	2
	3, 6, low Superrail	2
	3, 7, high Cr	2
	3, 8, low Cr	2
A26-28	3, 9, low Cr	2
	3, 10, high Cr	2
	3, 11, low Superrail	2
	3, 12, high Superrail	2
A29-31	3, 13, high Superrail	2
	3, 14, low Superrail	2
	3, 15, high Cr	2
	3, 16, low Cr	2

Table A1 (Contd.)

Location of Measurement Points

Figure No.	Applicable Test Site, Measurement Point(s) and Description	Figure Providing Location of Measurement Point in Relevant Test Site
A32-34	3, 17, low Cr	2
	3, 18, high Cr	2
	3, 19, low Superrail	2
	3, 20, high Superrail	2
A35-37	3, 21, low Superrail	2
	3, 22, high Superrail	2
	3, 23, low Cr	2
	3, 24, high Cr	2
A38	2, 1-20, average percentage reductions in wear achieved by Superrail in high and low rail positions	1
A39	3, 1-20, average percentage reductions in wear achieved by Superrail in high and low rail positions	2

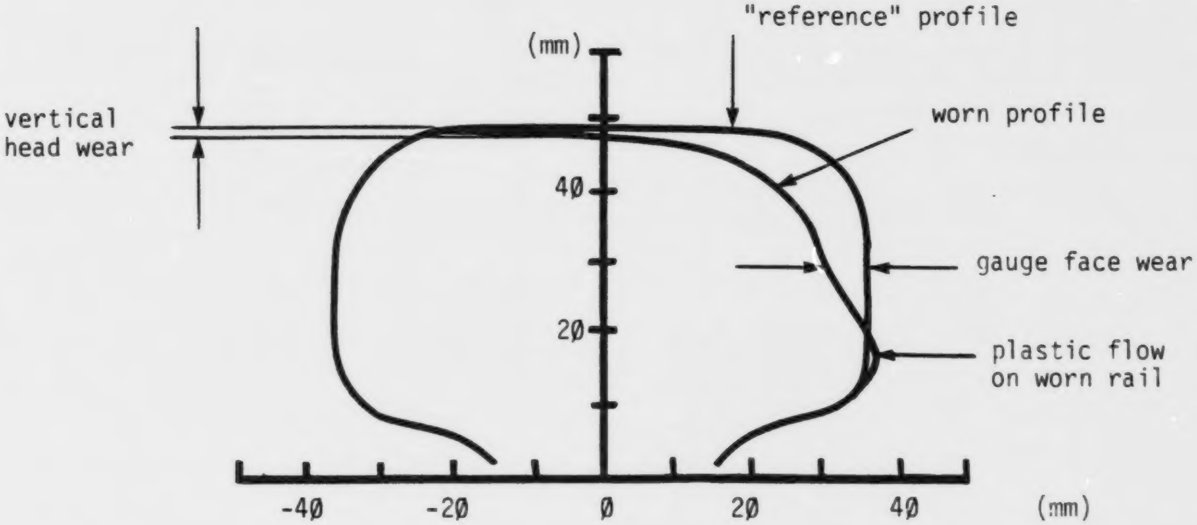
FILE: JR05 ID: 001025
FILE: JR45 ID: 001025



VERTICAL WEAR : 3.8 mm
GAUGE FACE WEAR : 10.3 mm
AREA OF WEAR : 477.2 sq.mm

Figure A1: Profile Comparison, Algoma 1% Cr, High Rail in Fully Developed Section of 8.5° Curve, Site #3, Change-Over Point #1, Measurement Point #2

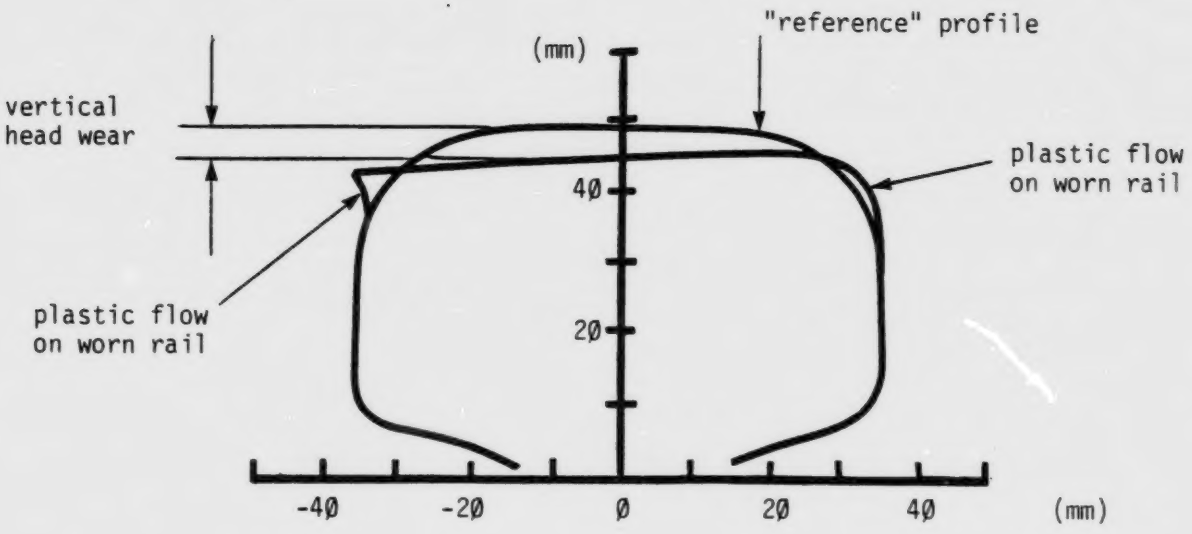
FILE: JR05 ID: 301045
FILE: JR45 ID: 301045



VERTICAL WEAR : 1.3 mm
GAUGE FACE WEAR : 6.0 mm
AREA OF WEAR : 250.1 sq.mm

Figure A2: Profile Comparison, Japanese Superrail, High Rail in Fully Developed Section of 8.5° Curve, Site #3, Change-Over Point #1, Measurement Point #4

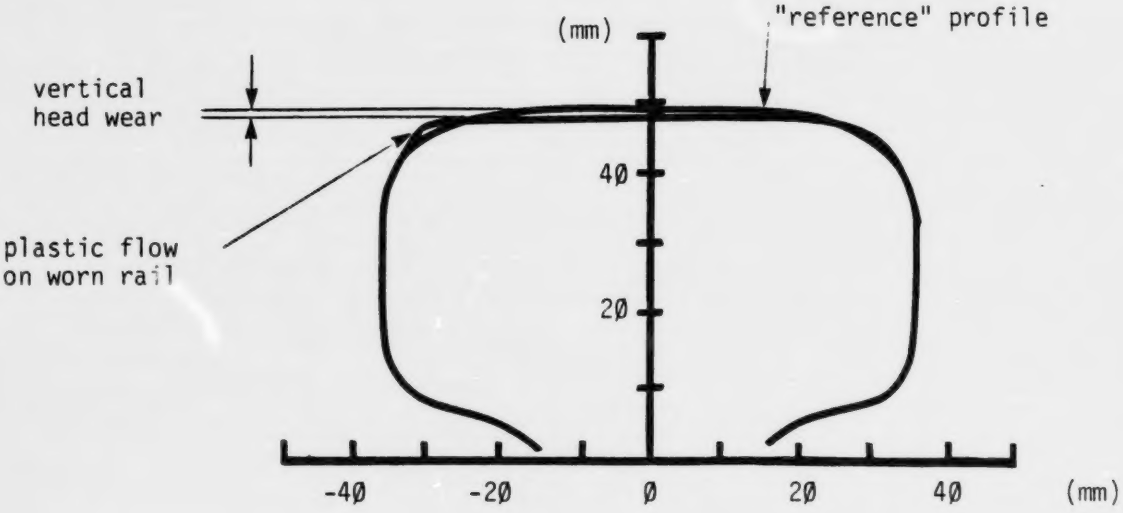
FILE: JR05 ID: 000015
FILE: JR45 ID: 000015


vertical
head wear
"reference" profile
(mm)
plastic flow
on worn rail
plastic flow
on worn rail
40
20
-40
-20
0
20
40
(mm)

VERTICAL WEAR	:	4.4 mm
GAUGE FACE WEAR	:	0.0 mm
AREA OF WEAR	:	208.8 sq.mm

Figure A3: Profile Comparison, Algoma 1% Cr, Low Rail in Fully Developed Section of 8.5° Curve, Site #3, Change-Over Point #1, Measurement Point #1

FILE: JR05 ID: 300035
FILE: JR45 ID: 300035



VERTICAL WEAR : 1.4 mm
GAUGE FACE WEAR : 0.0 mm
AREA OF WEAR : 57.6 sq.mm

Figure A4: Profile Comparison, Japanese Superrail, Low Rail in Fully Developed Section of 8.5° Curve, Site #3, Change-Over Point #1, Measurement Point #3

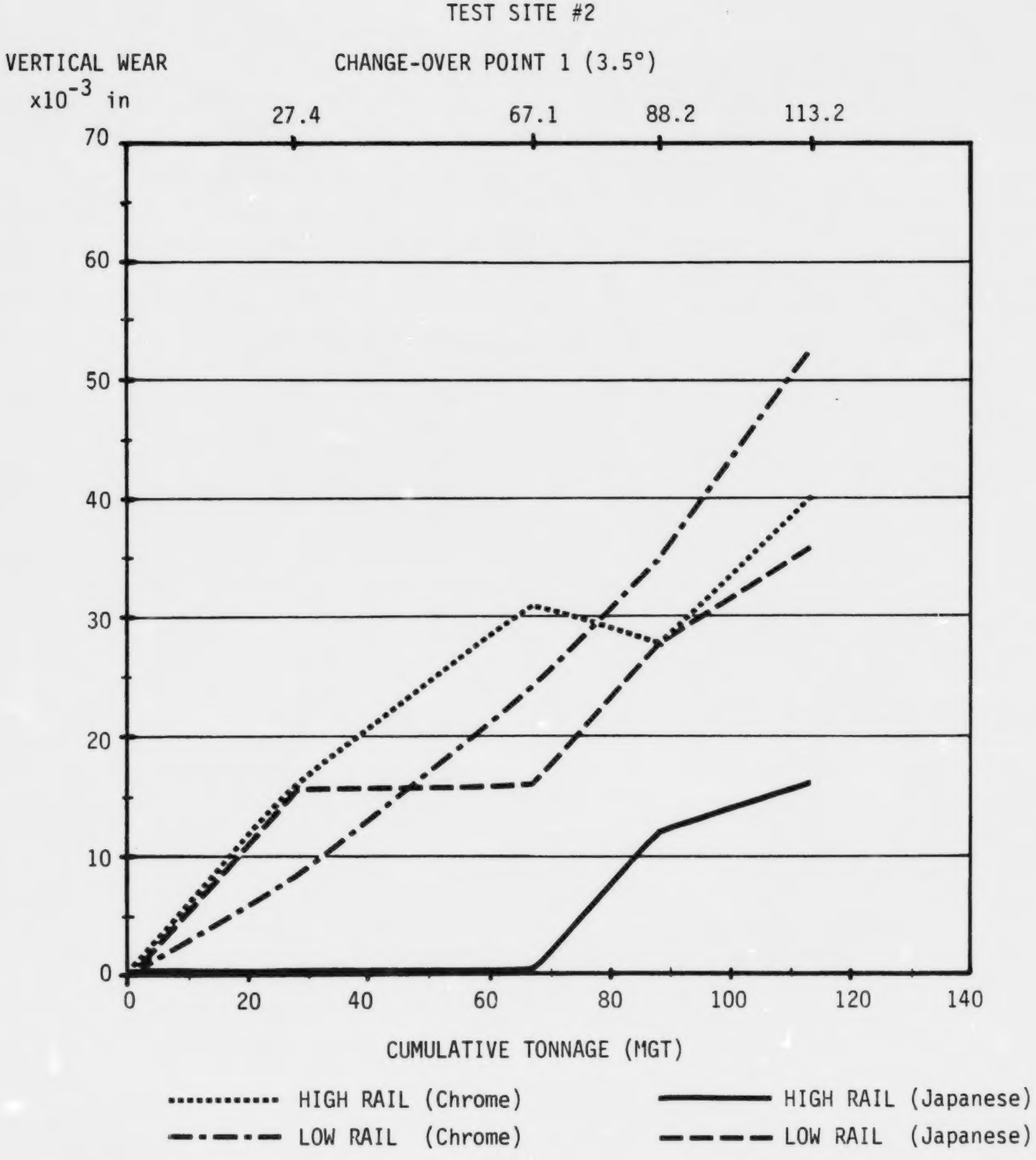


Figure A5: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 3.5° Curve, For Algoma 1% Cr and Japanese Superrail

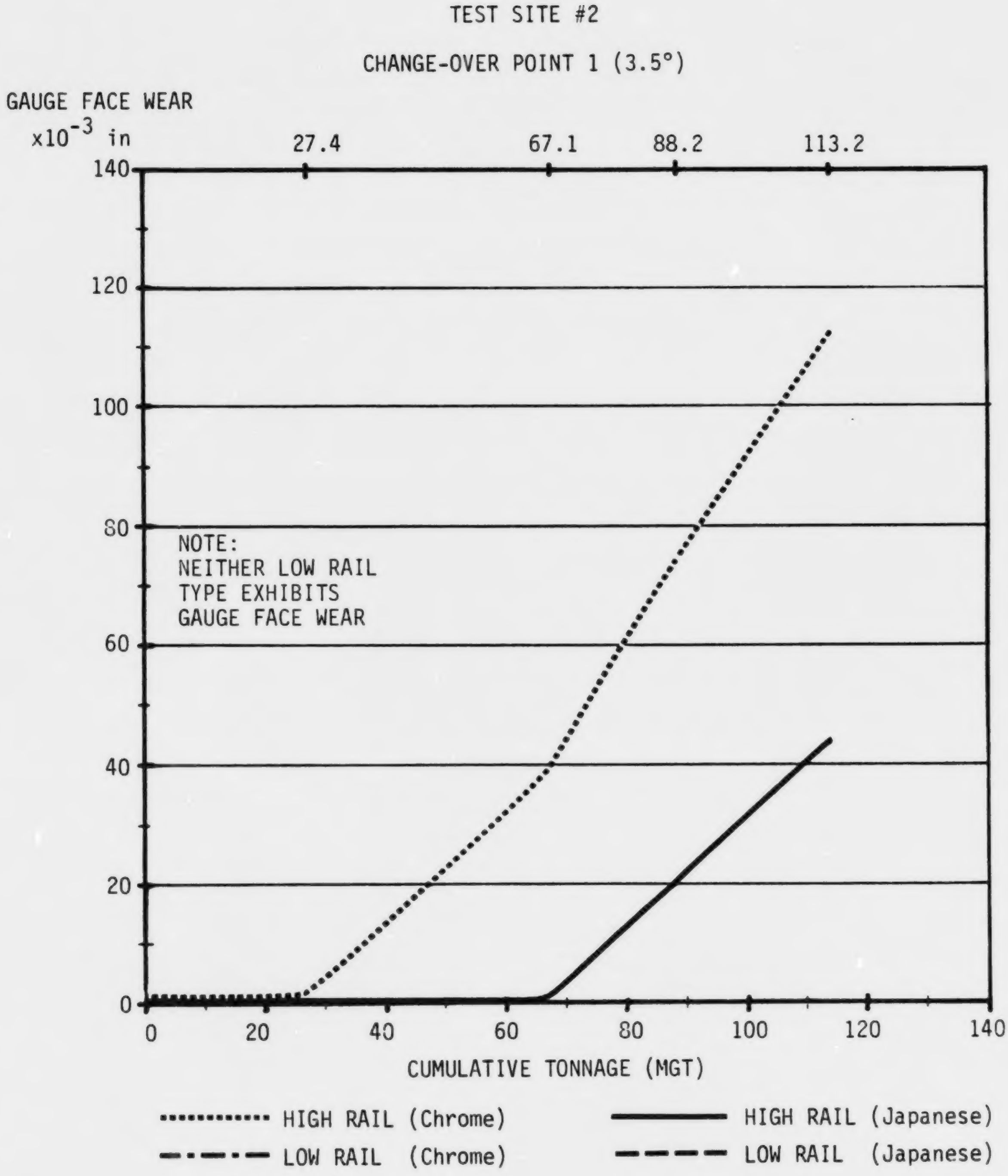
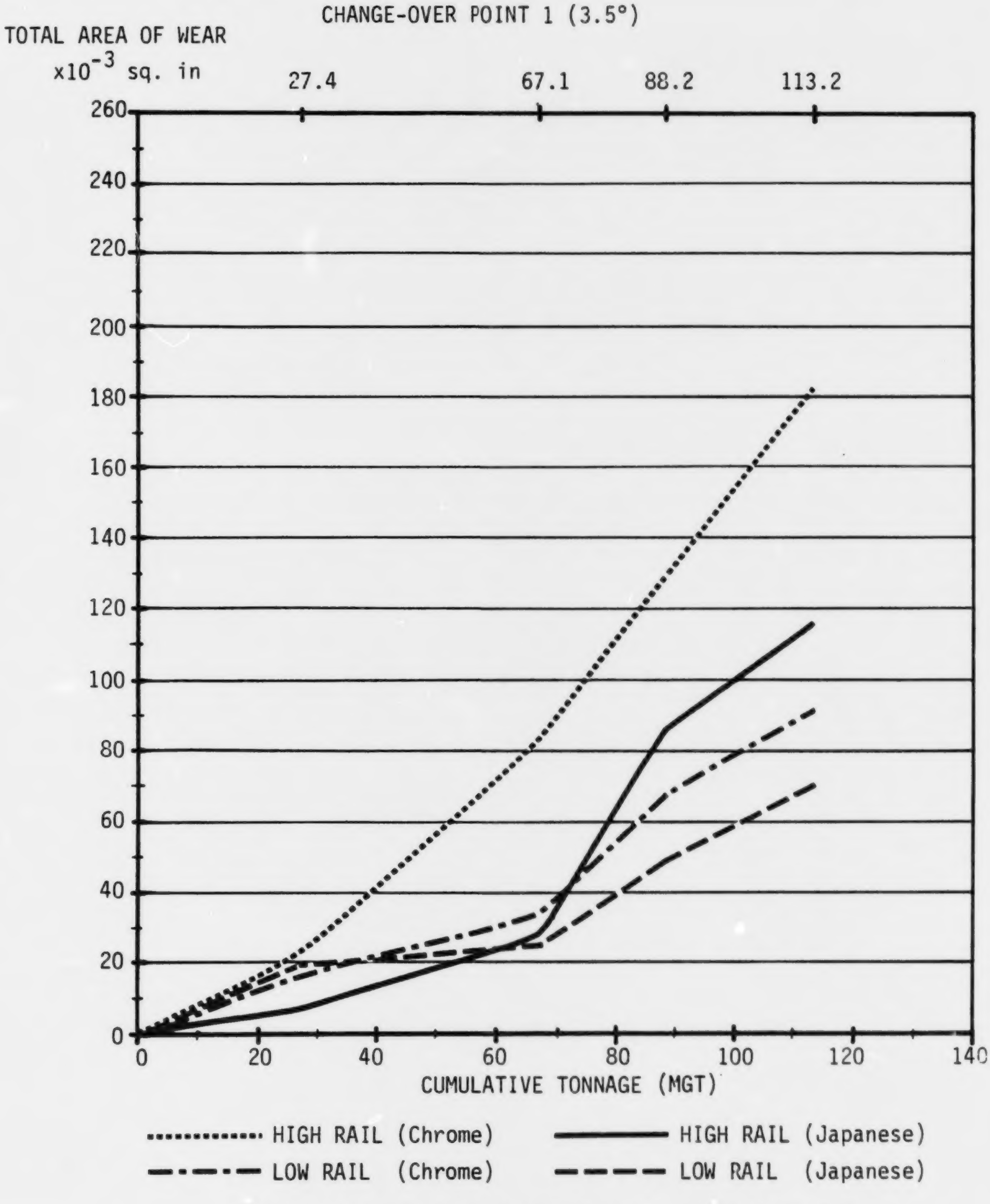


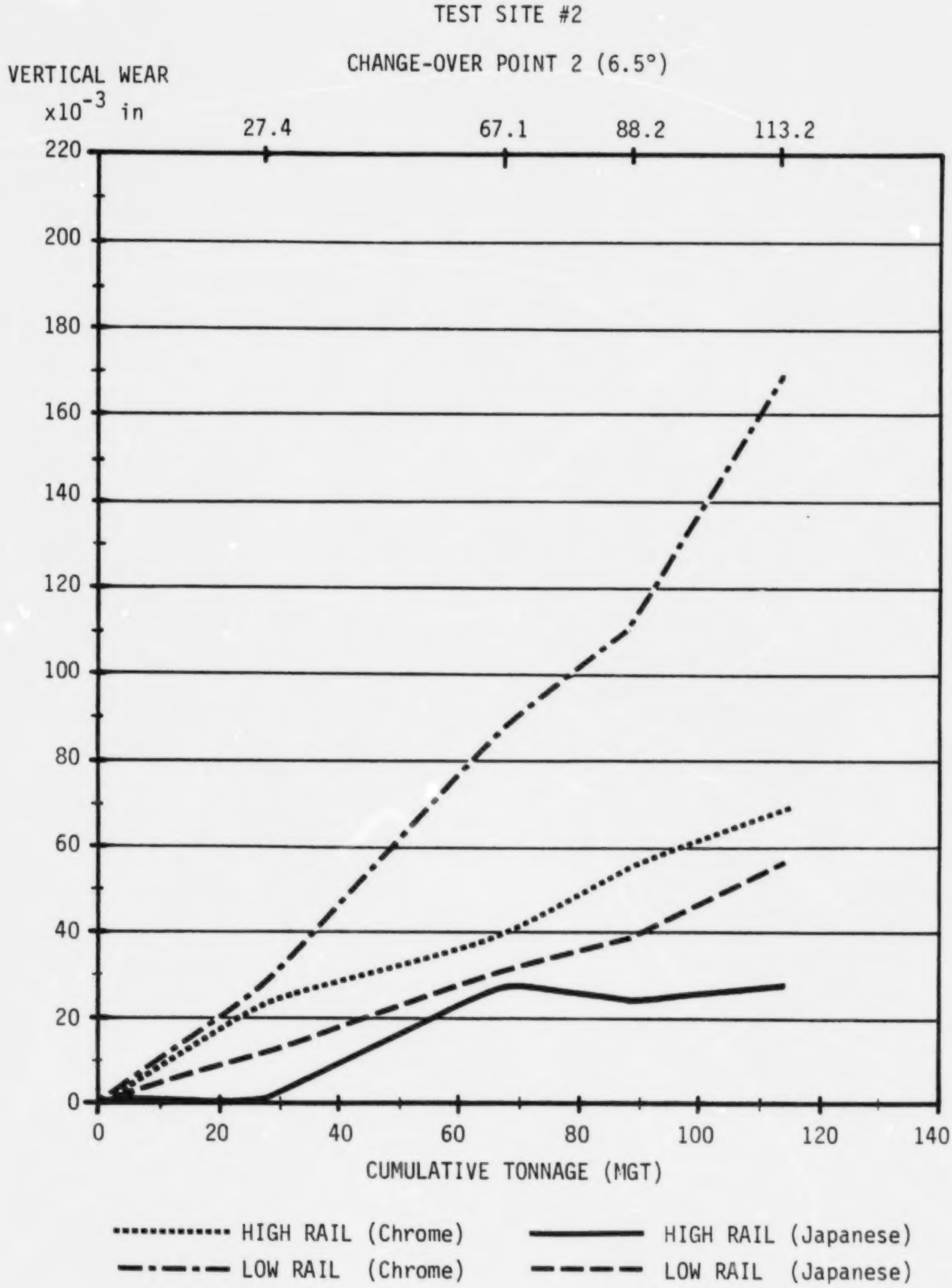
Figure A6: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of a 3.6° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #2

CHANGE-OVER POINT 1 (3.5°)

Figure A7: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 3.5° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #2

CHANGE-OVER POINT 2 (6.5°)

Figure A8: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail

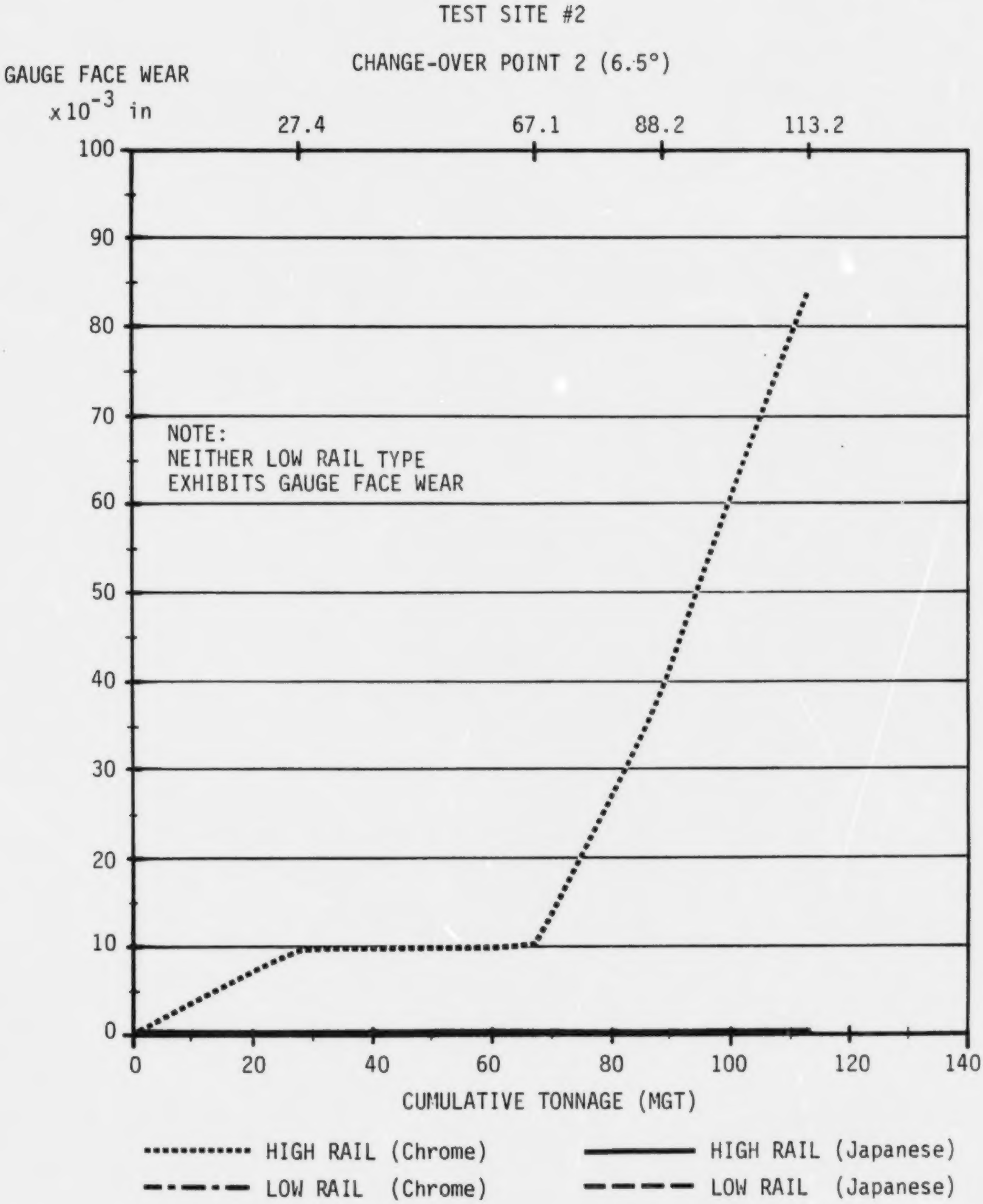


Figure A9: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail

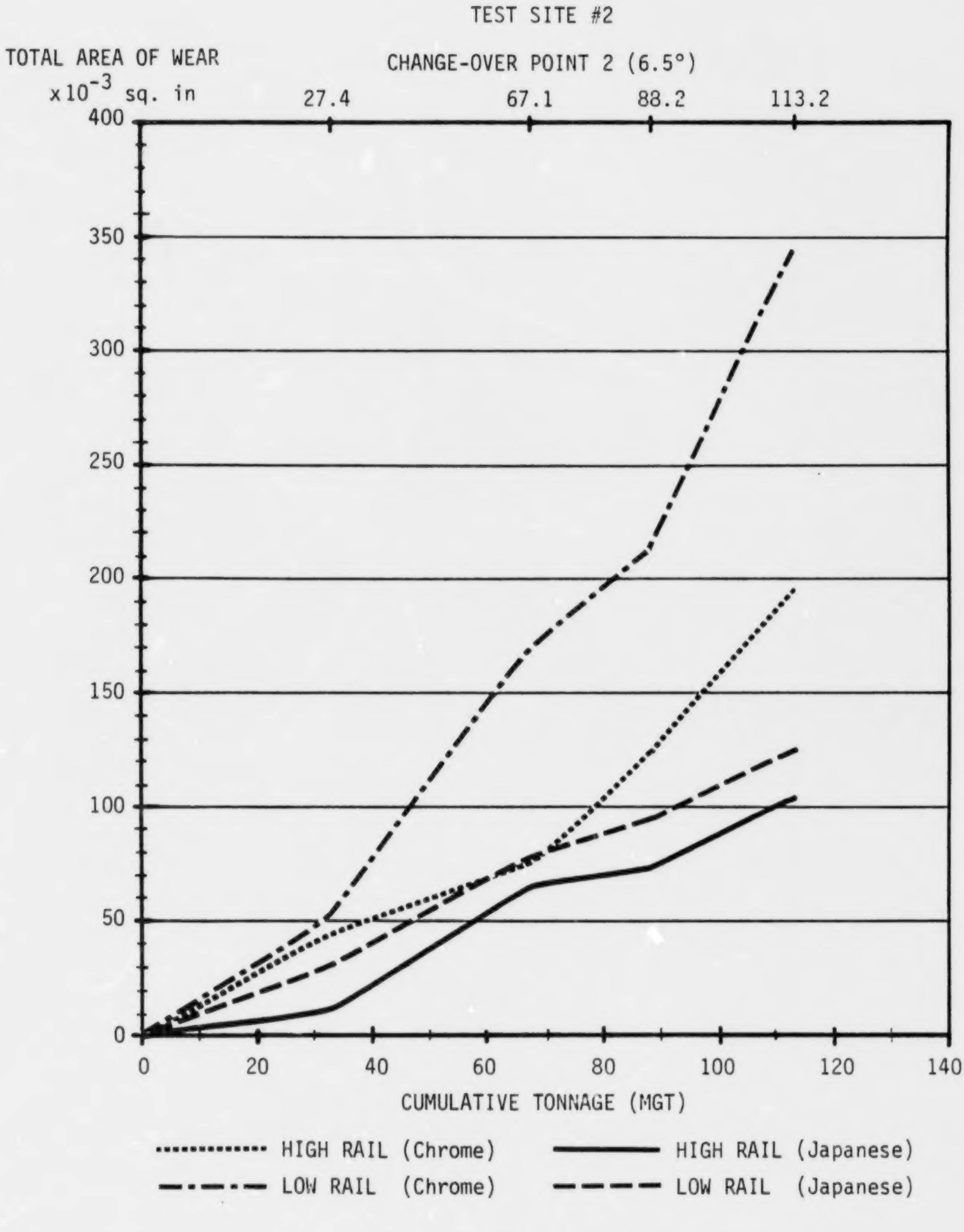


Figure A10: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #2

CHANGE-OVER POINT 3 (8.5°)

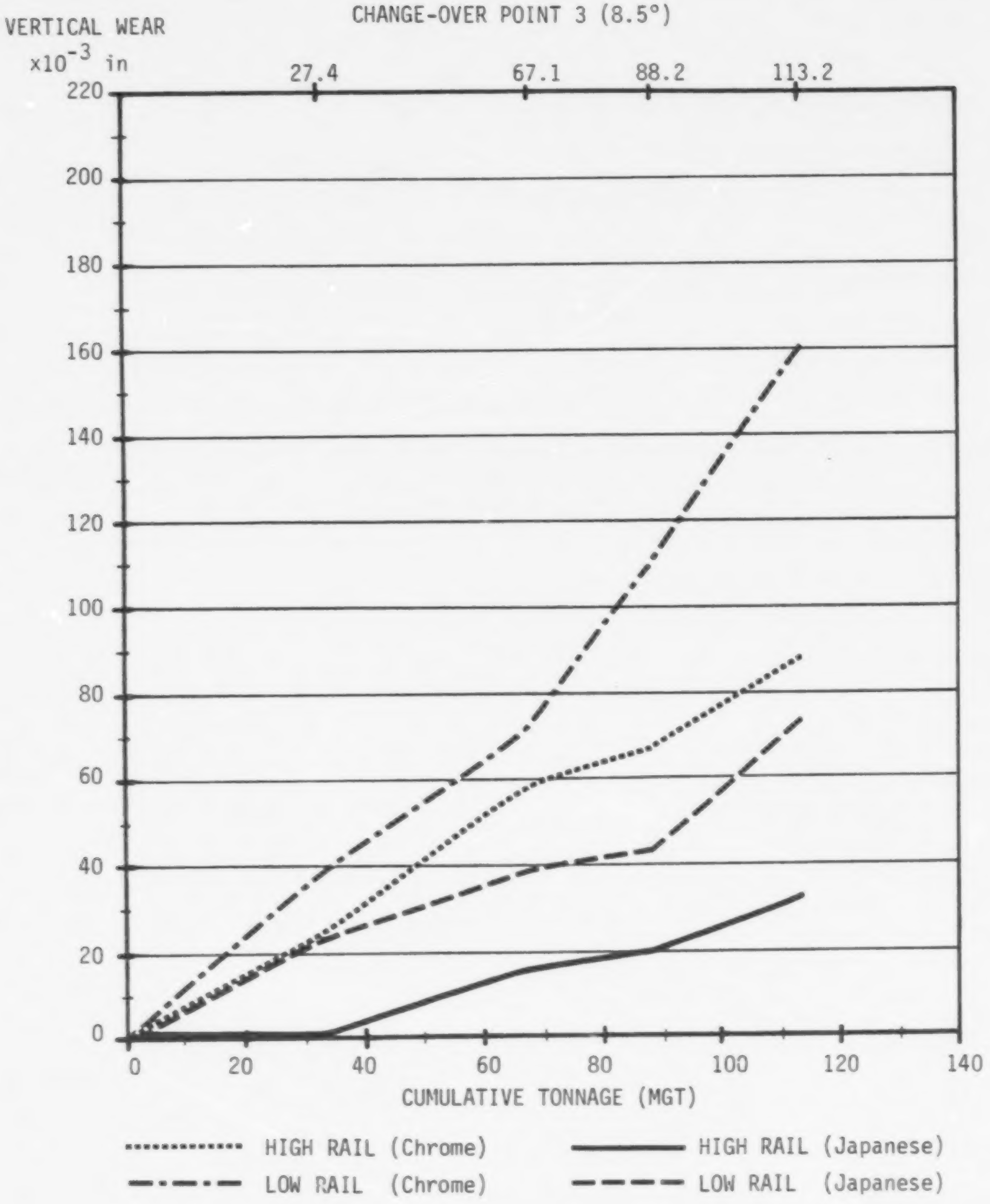


Figure A11: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

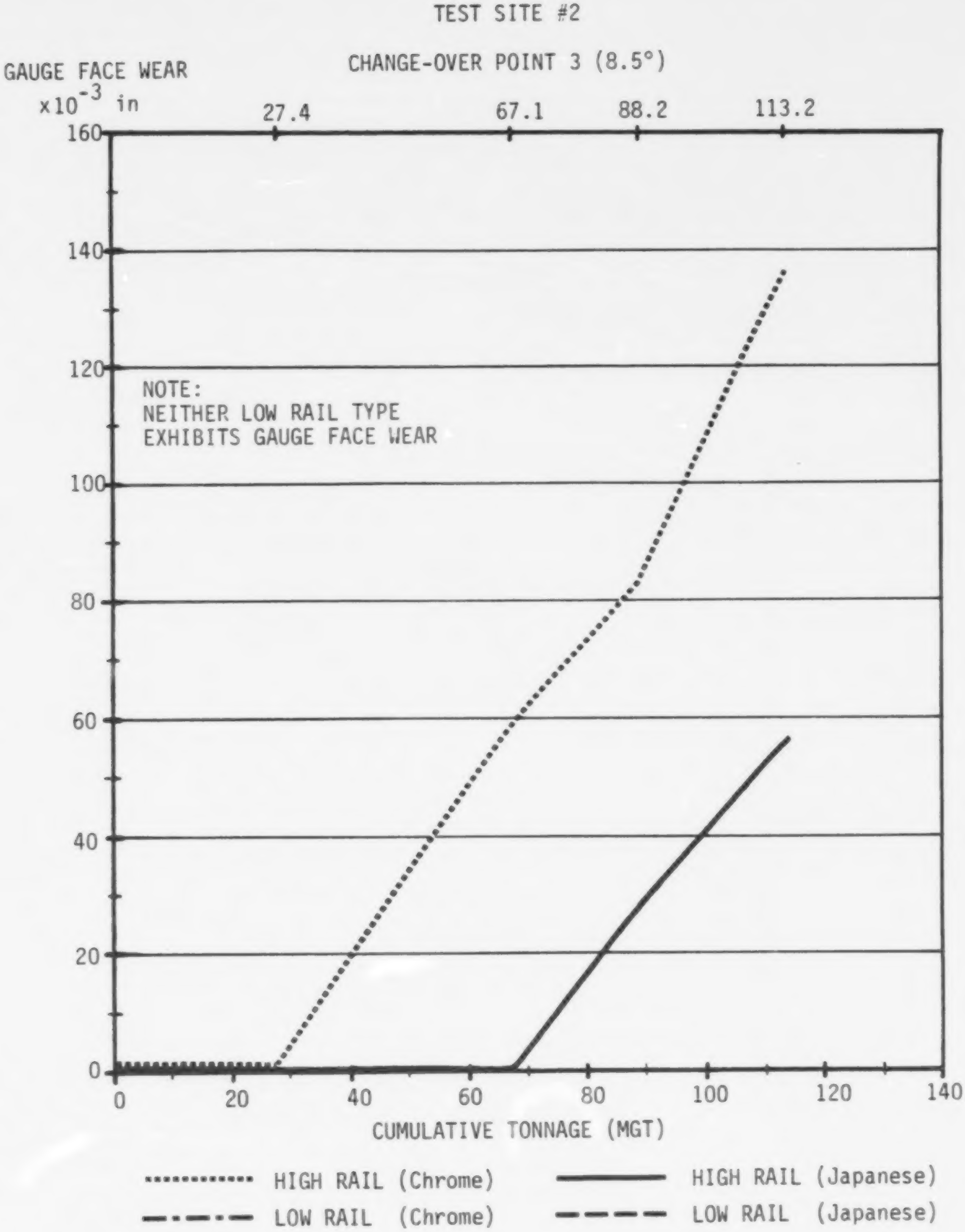


Figure A12: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #2

CHANGE-OVER POINT 3 (8.5°)

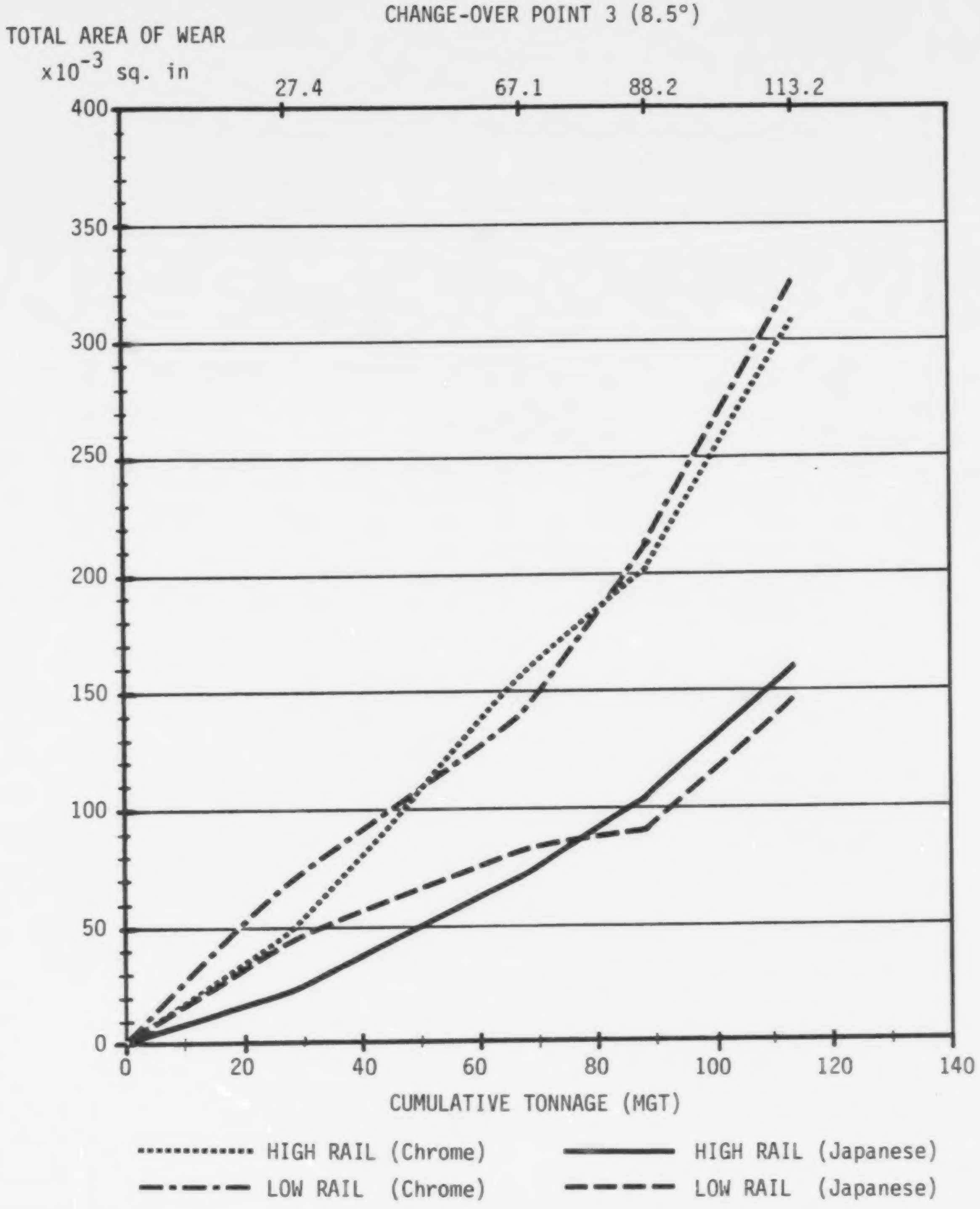


Figure A13: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #2

CHANGE-OVER POINT 4 (4.5°)

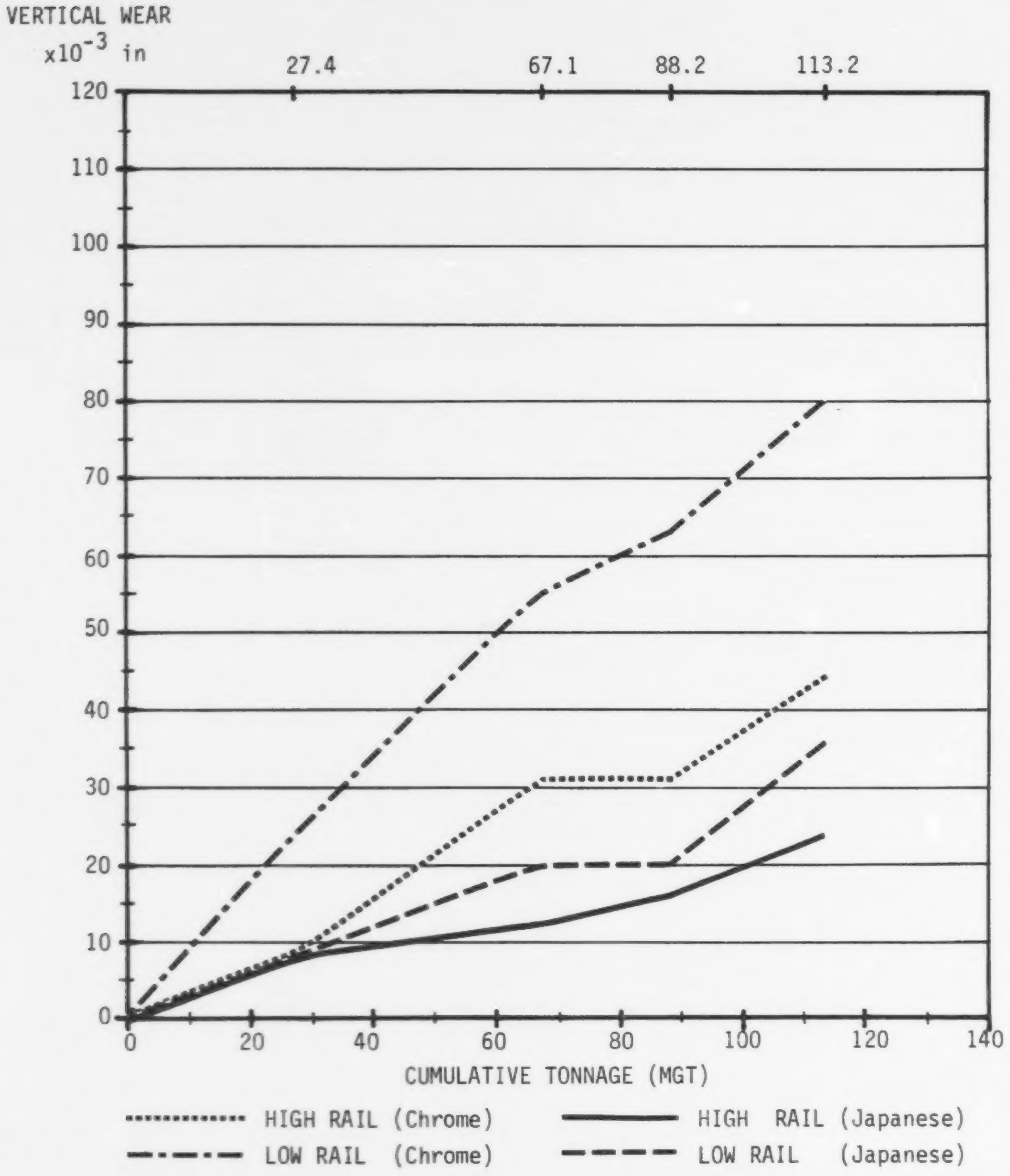


Figure A14: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 4.5° Curve, For Algoma 1% Cr and Japanese Superrail

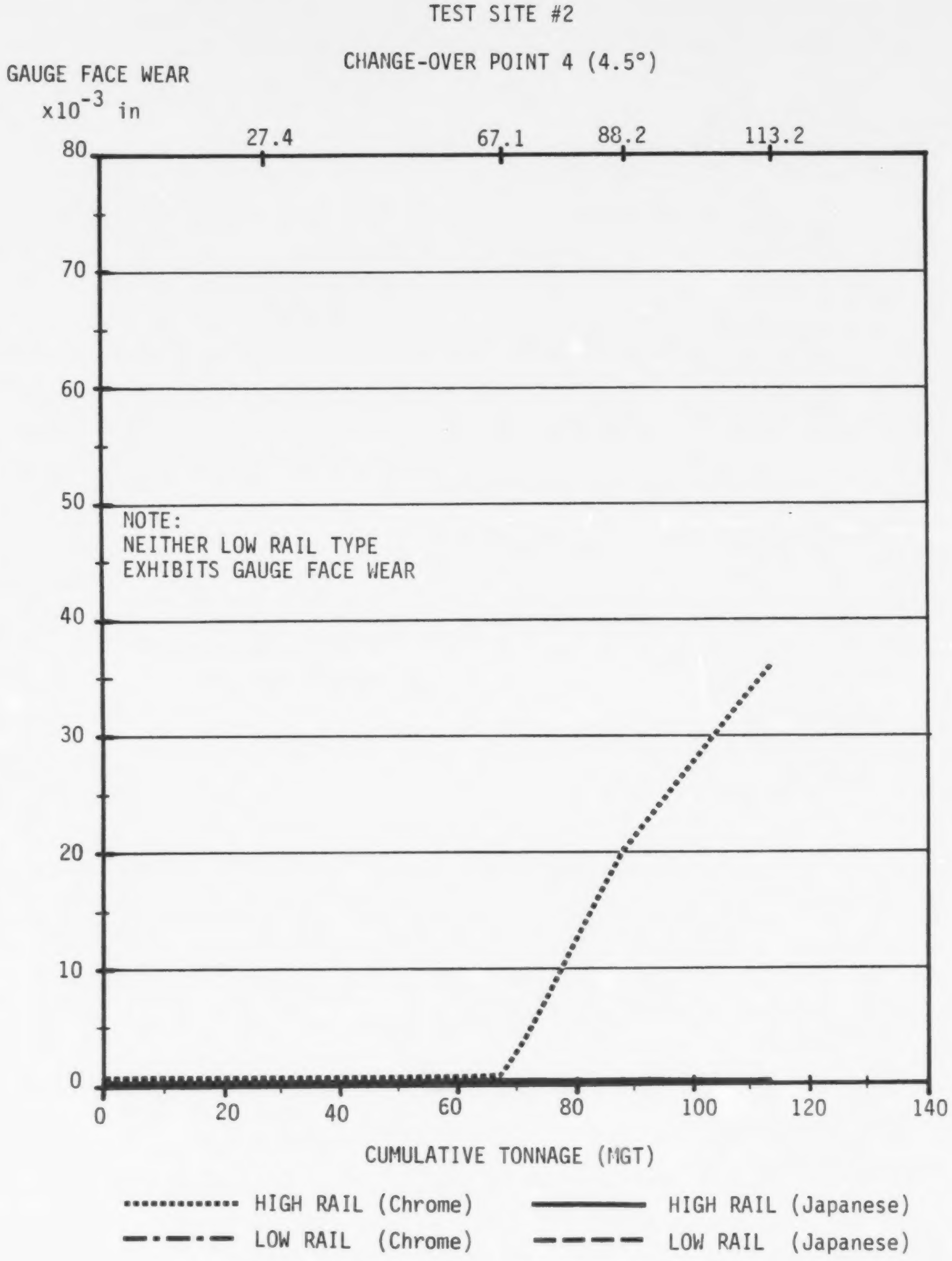


Figure A15: Gauge Face Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 4.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #2

CHANGE-OVER POINT 4 (4.5°)

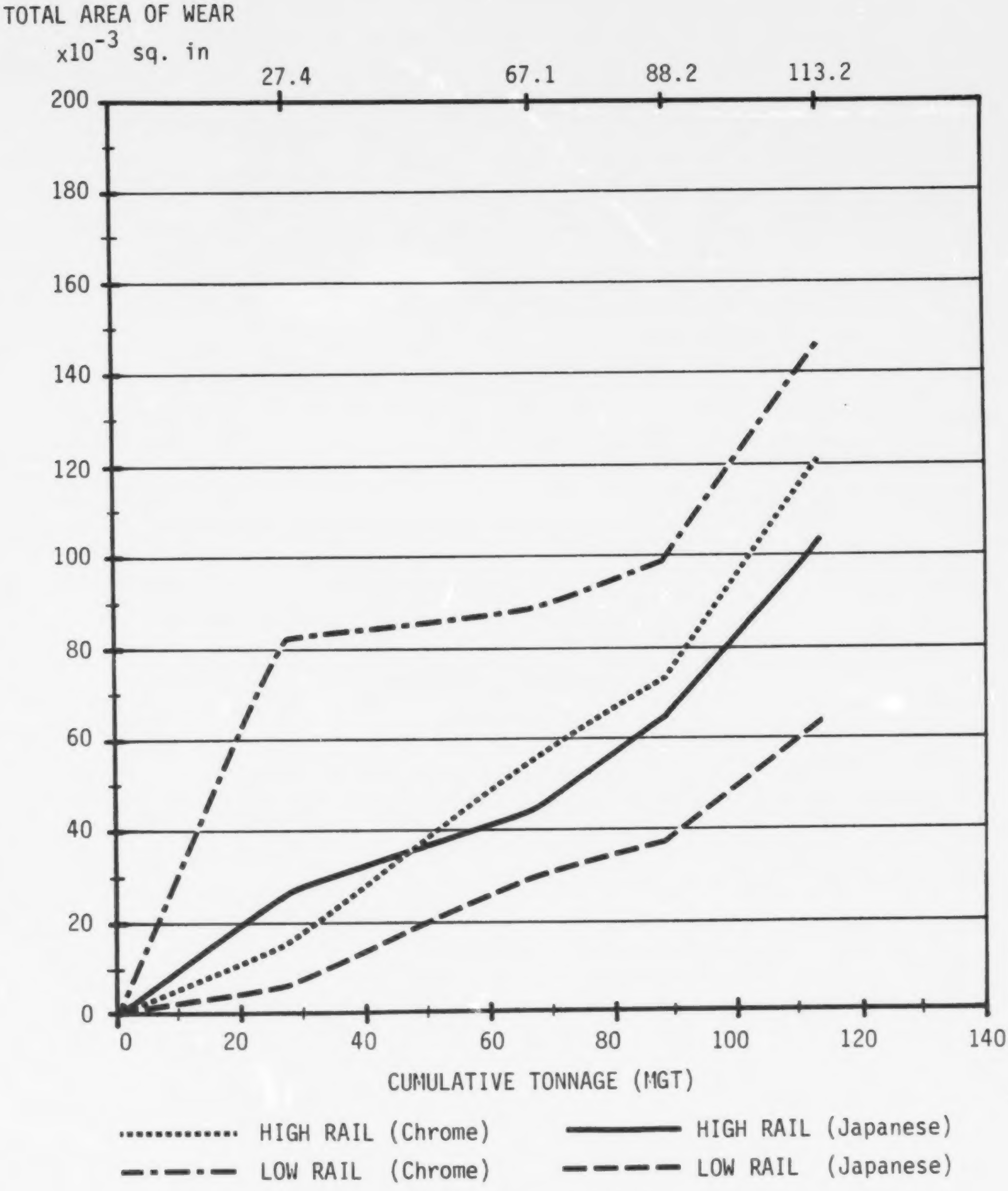


Figure A16: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 4.5° Curve, For Algoma 1% Cr and Japanese Superrail

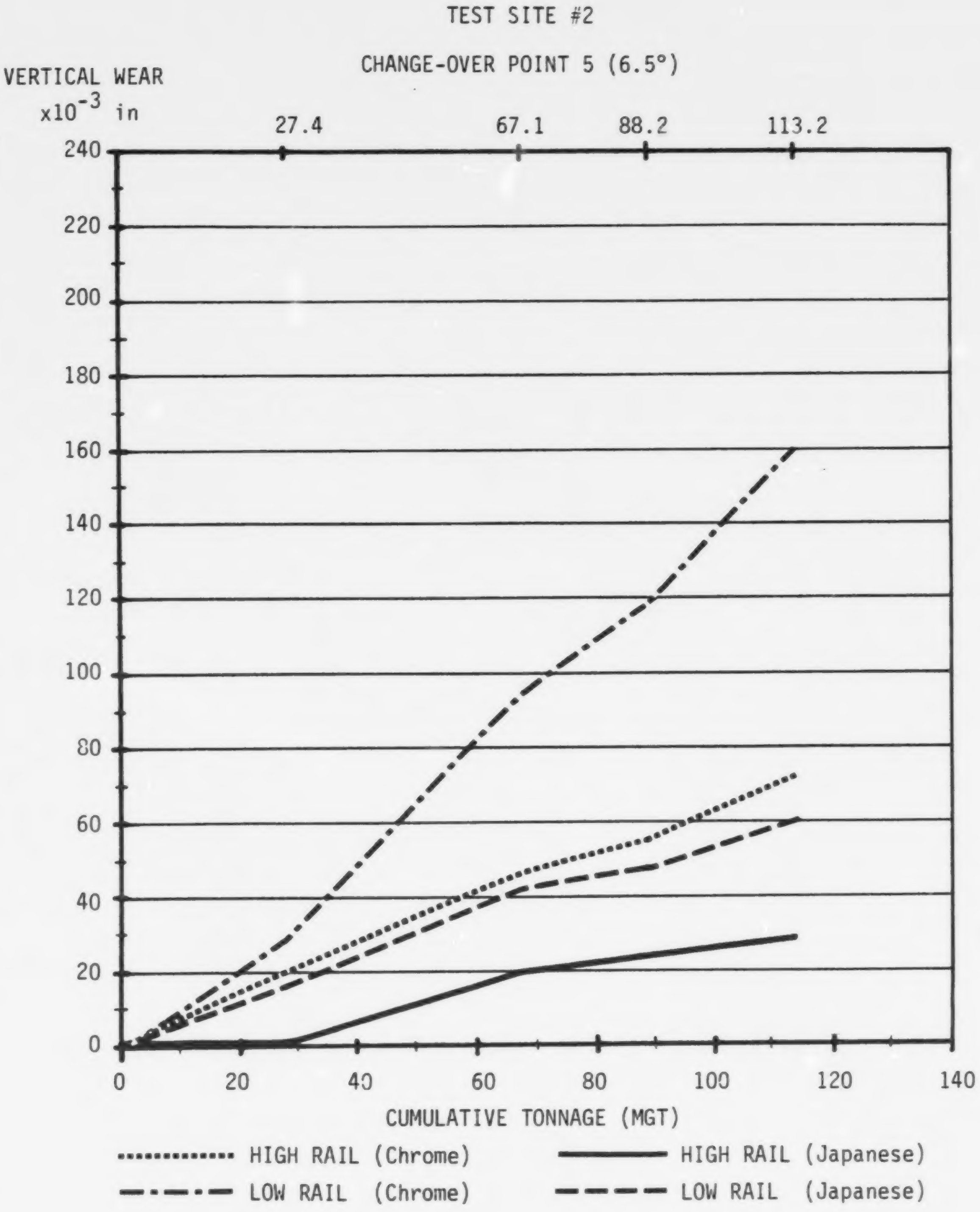


Figure A17: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail

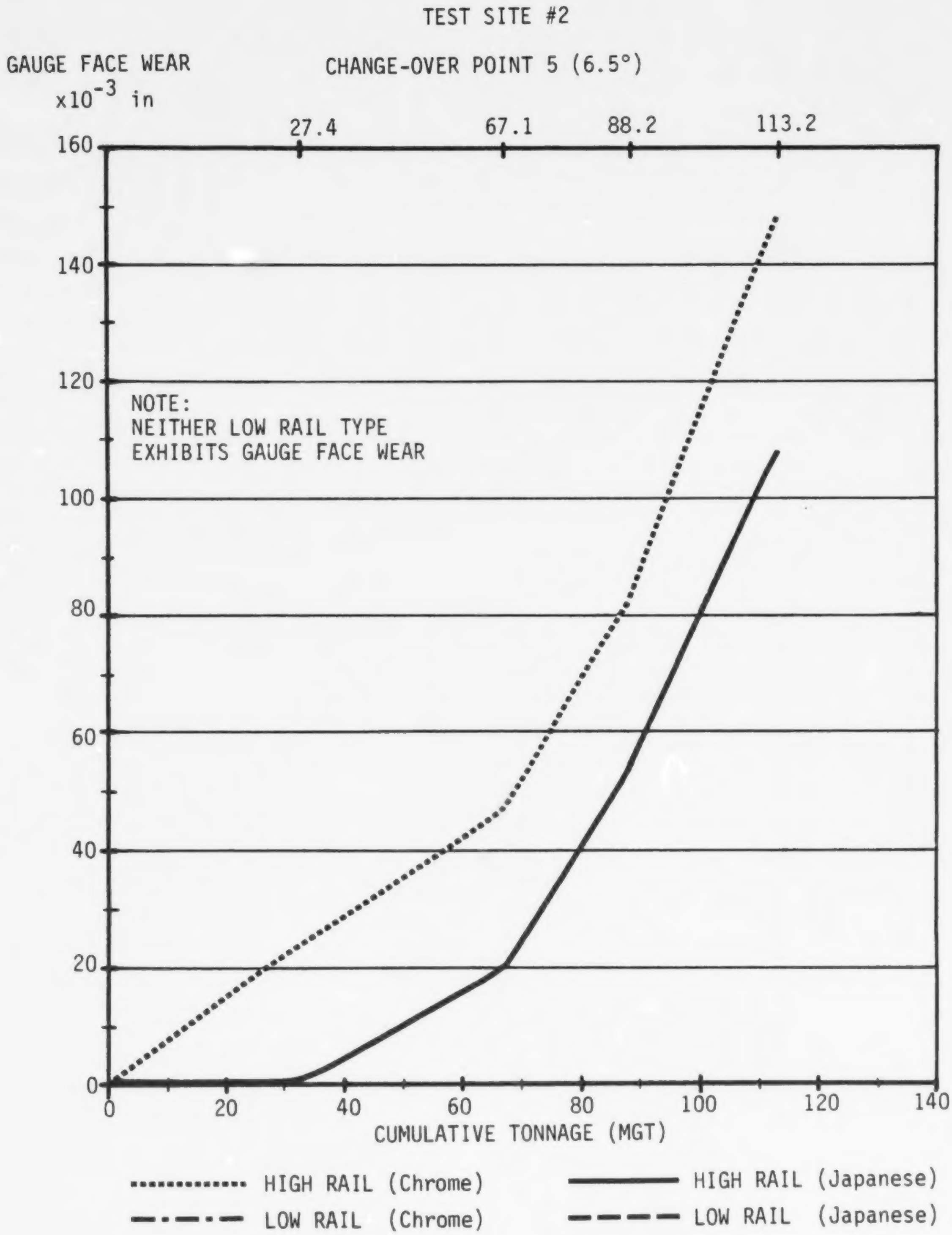
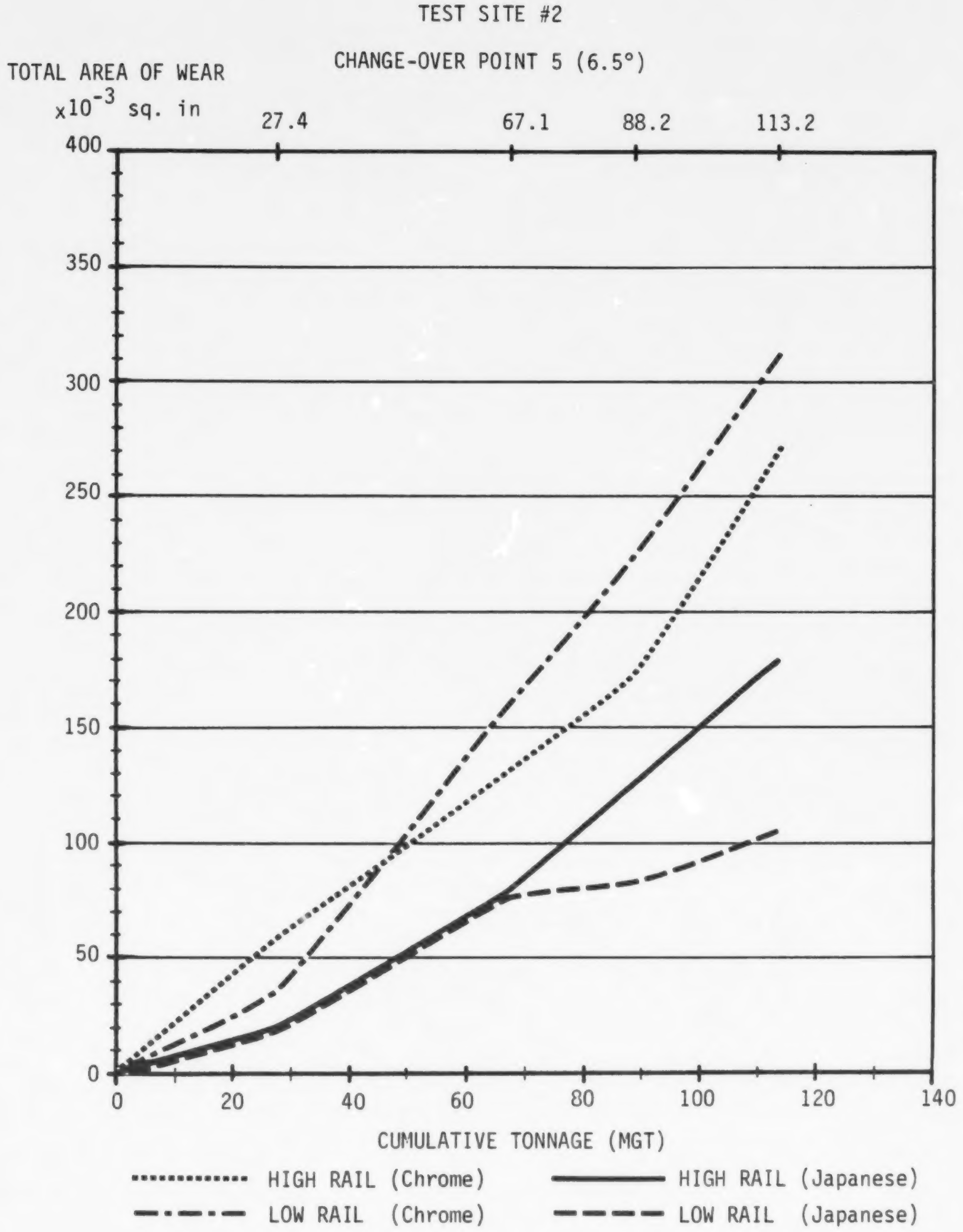


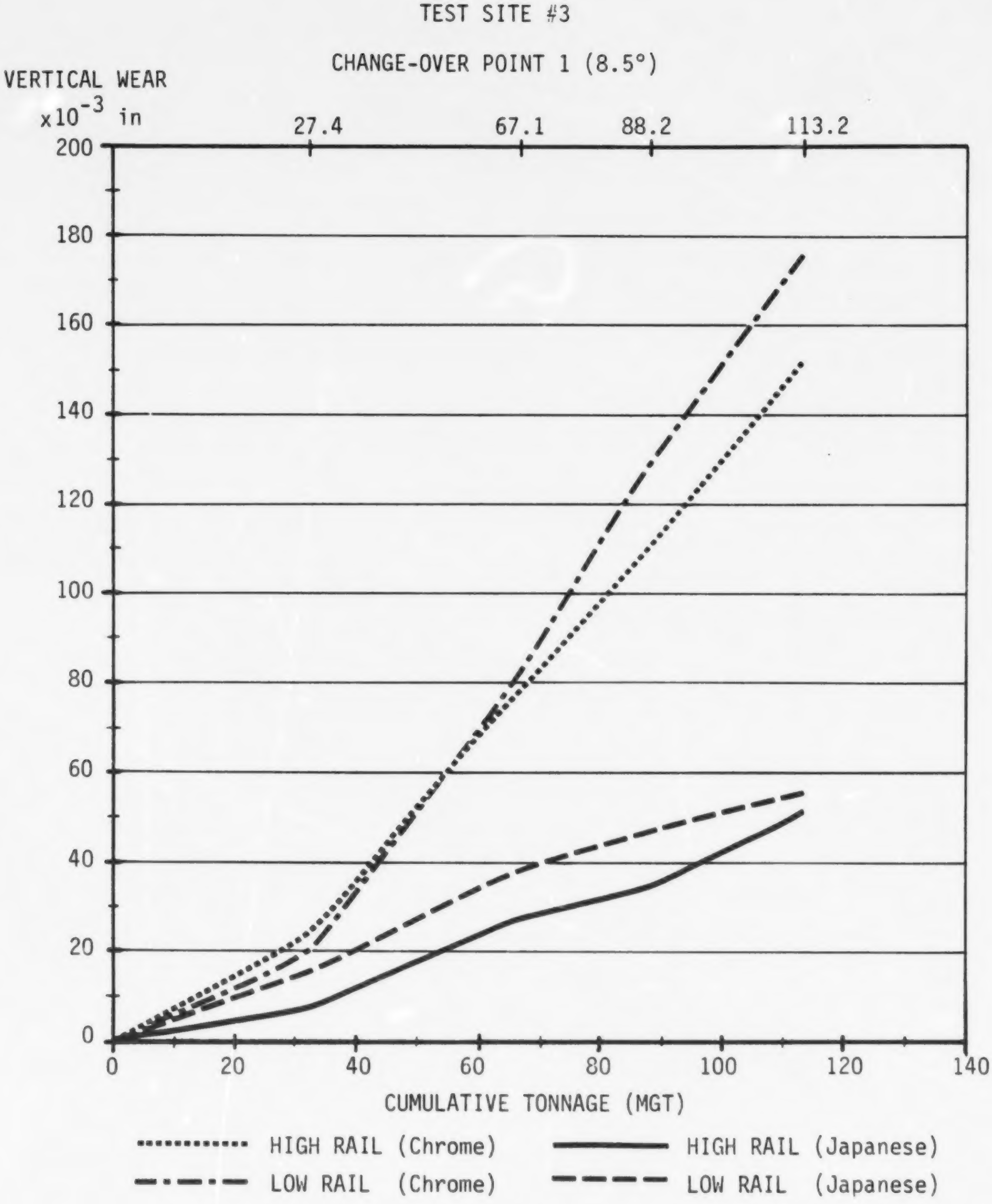
Figure A18: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #2

CHANGE-OVER POINT 5 (6.5°)

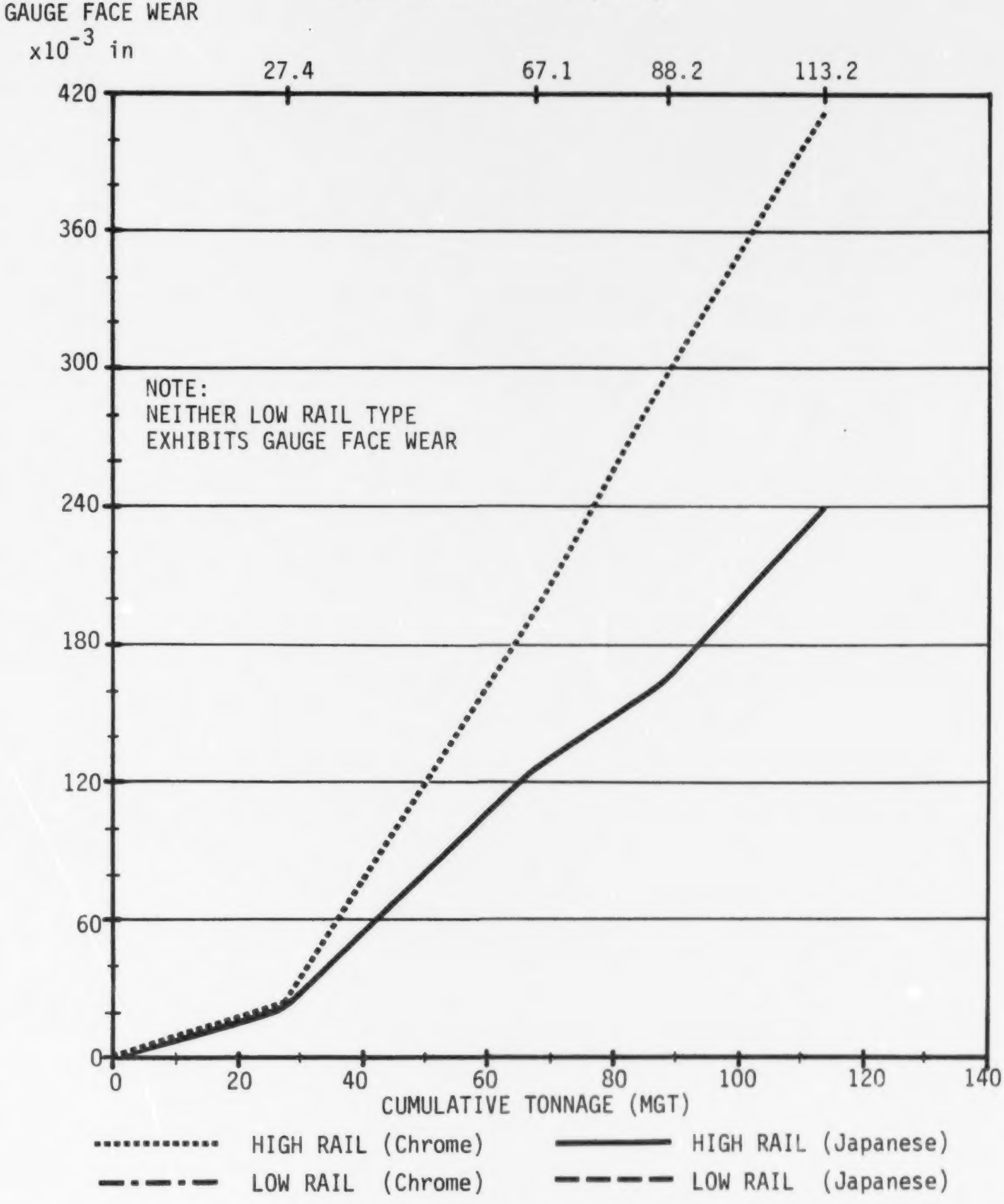
Figure A19: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of a 6.5° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #3

CHANGE-OVER POINT 1 (8.5°)

Figure A20: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrails



TEST SITE #3

CHANGE-OVER POINT 1 (8.5°)

Figure A21: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

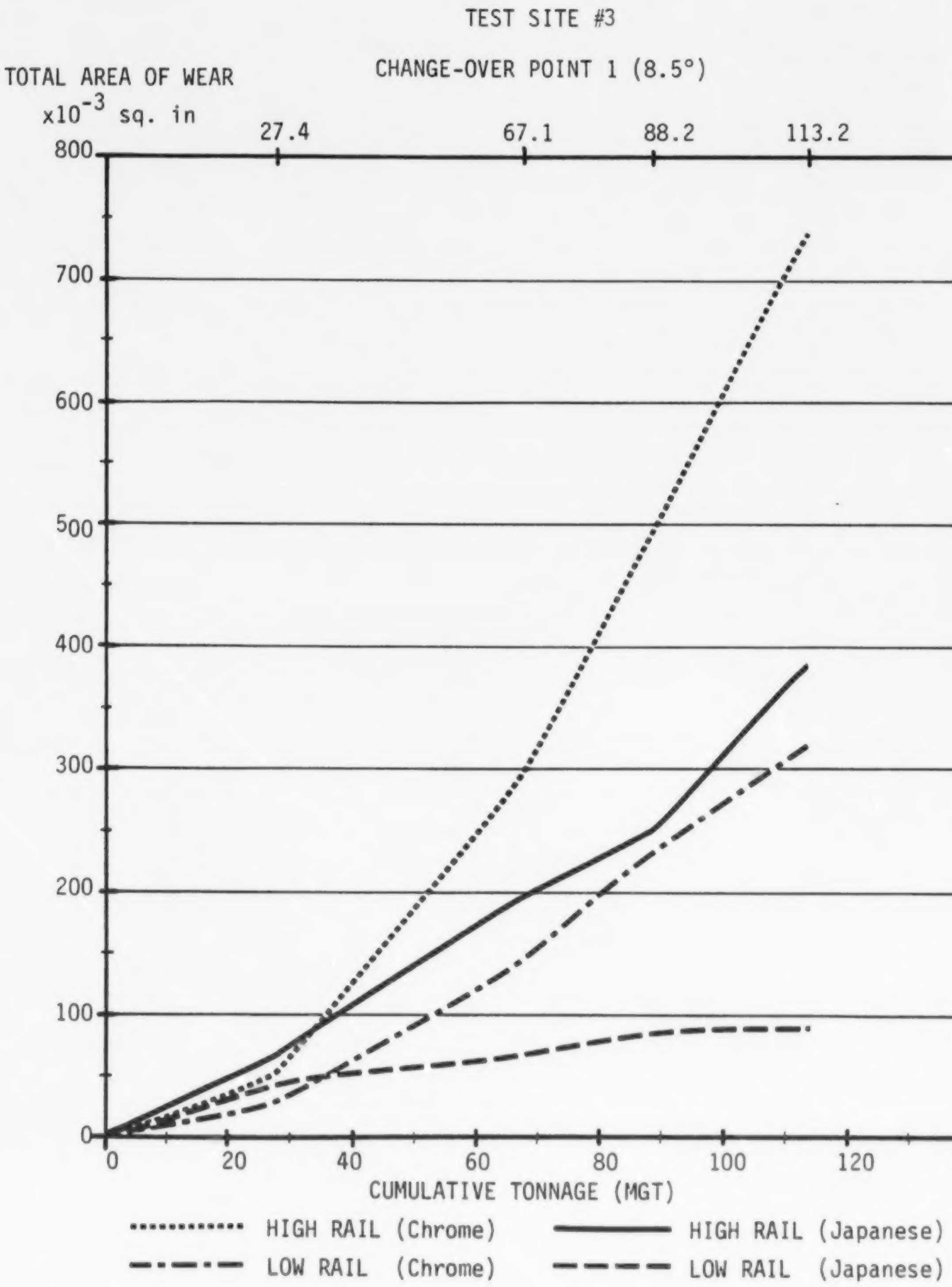


Figure A22: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

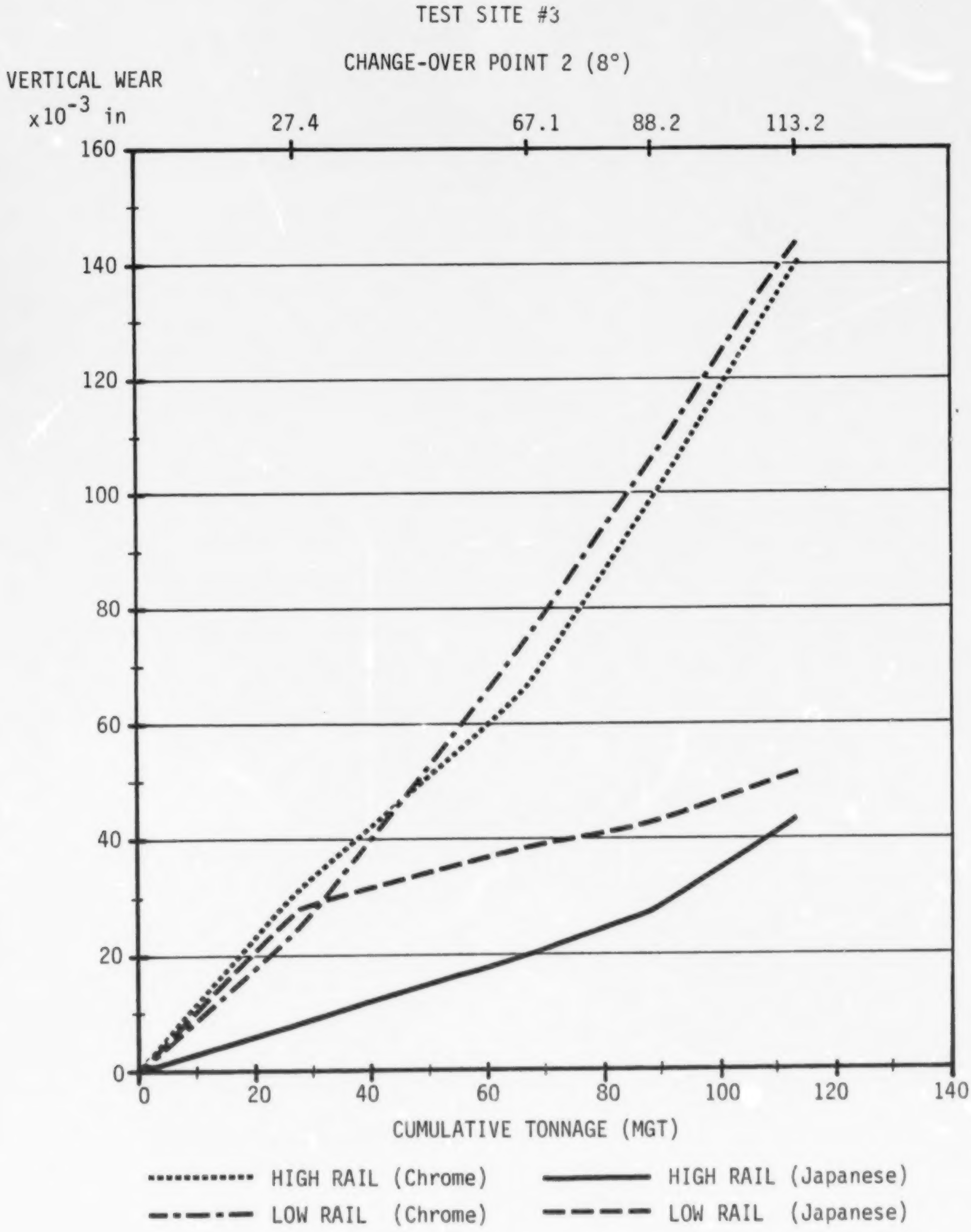


Figure A23: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail

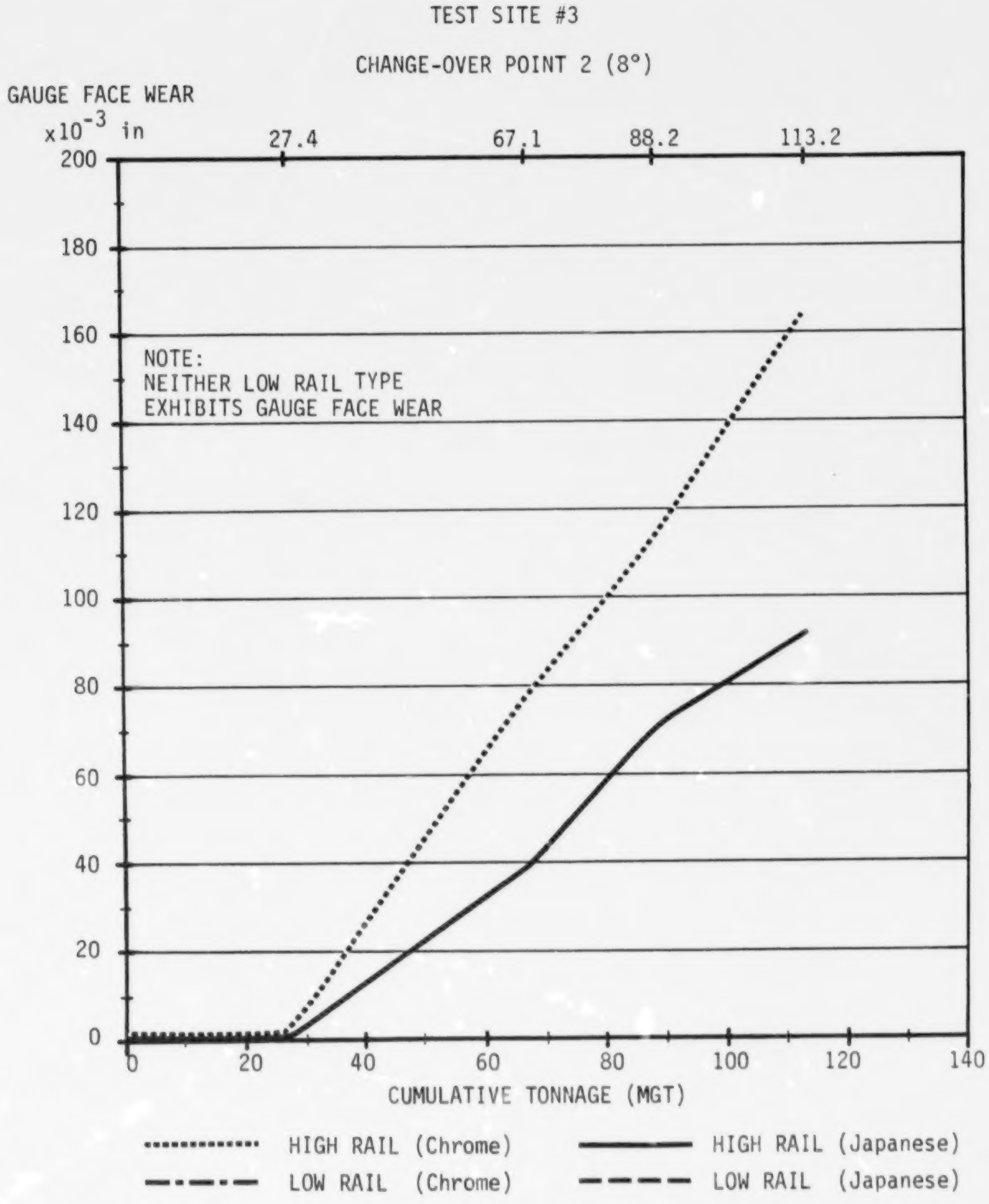
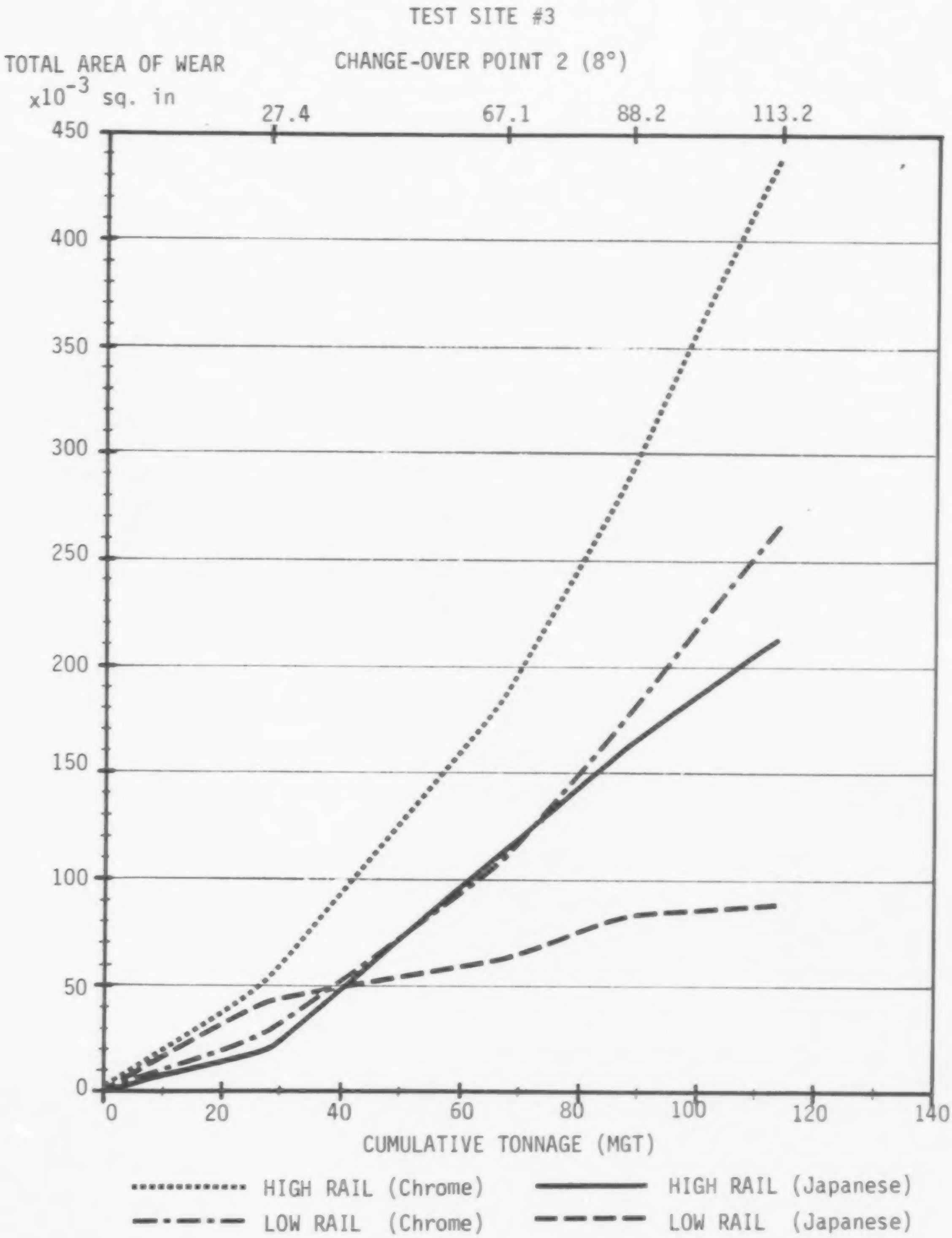


Figure A24: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #3

CHANGE-OVER POINT 2 (8°)

Figure A25: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail

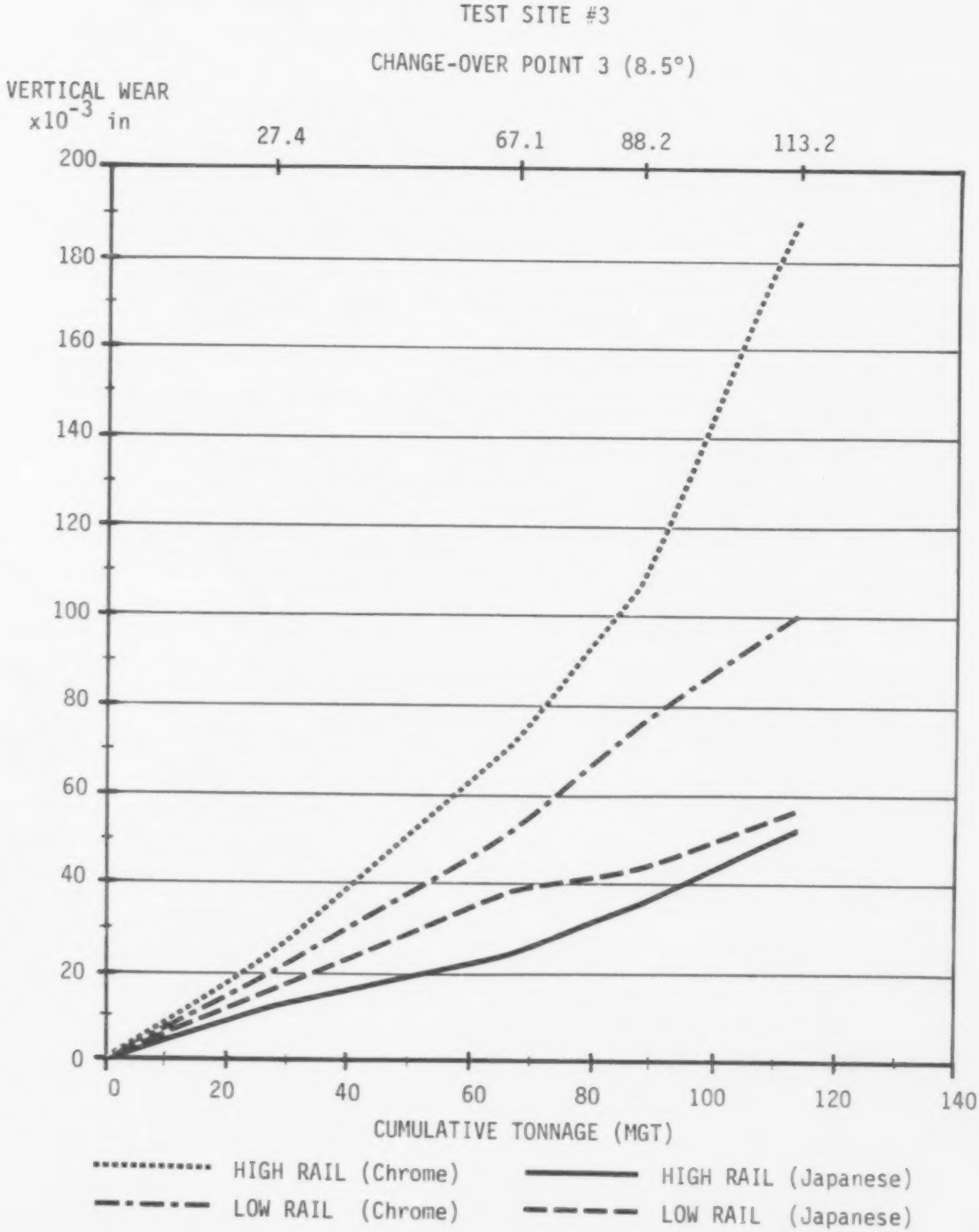


Figure A26: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

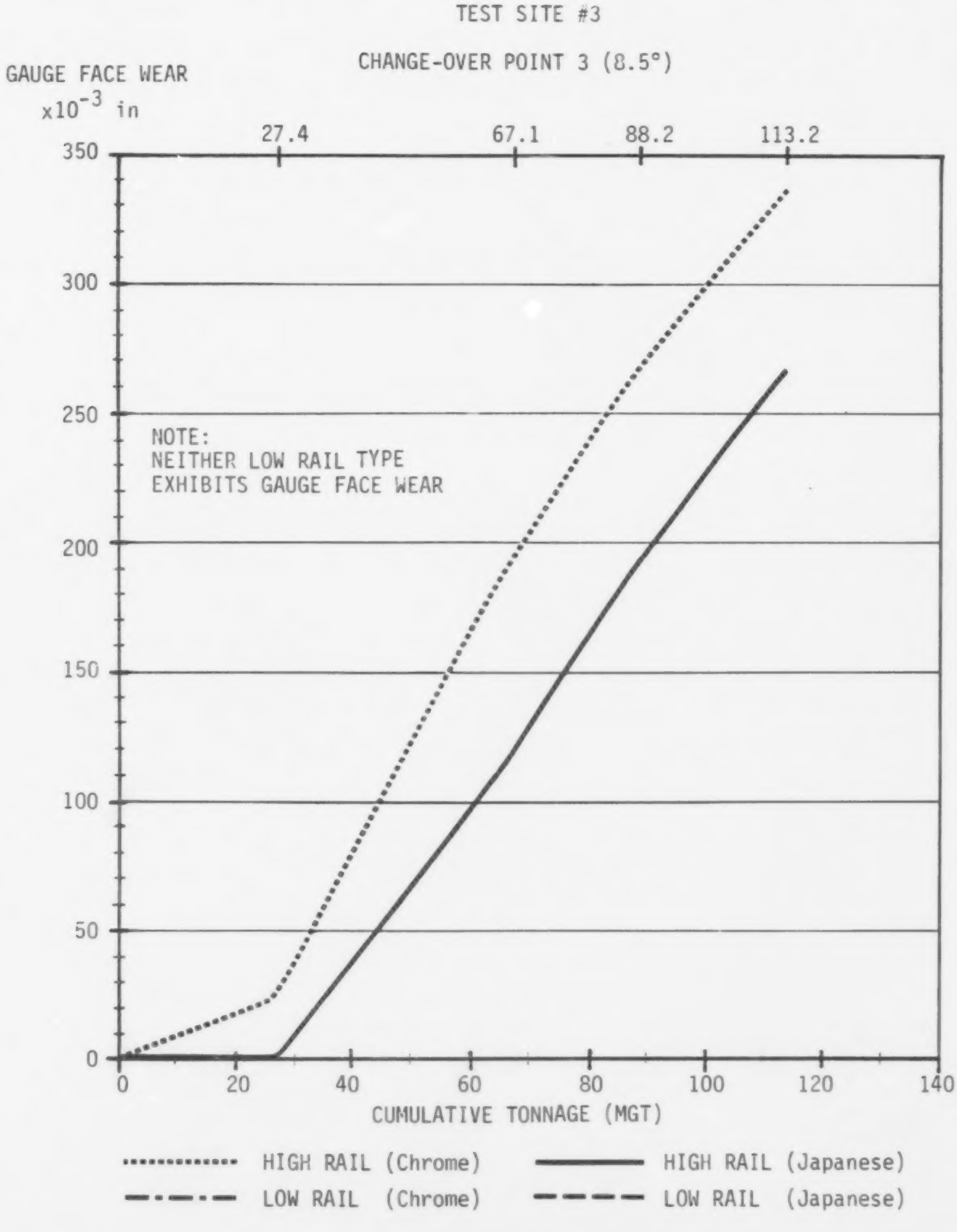


Figure A27: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

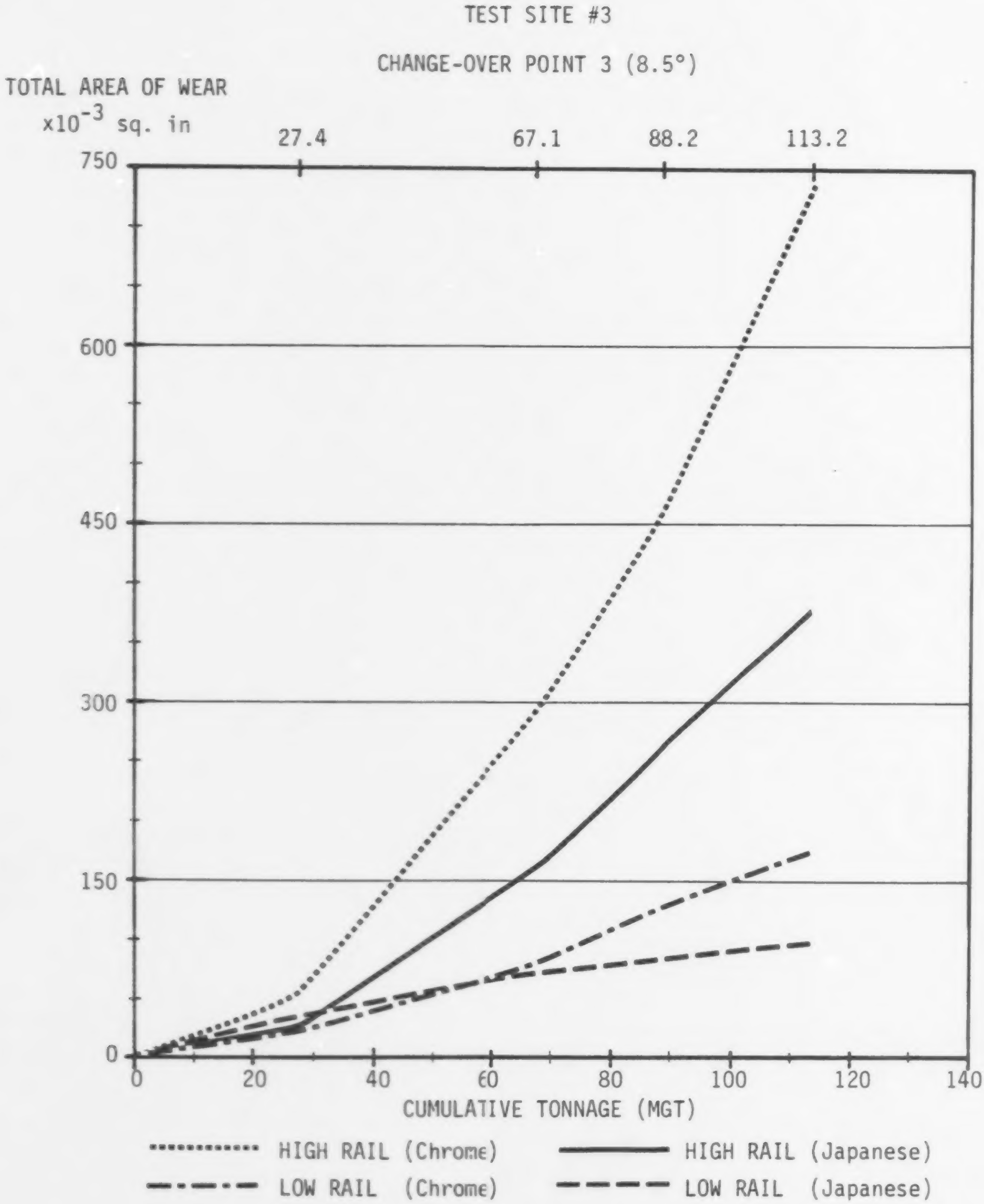


Figure A28: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #3

CHANGE-OVER POINT 4 (8.5°)

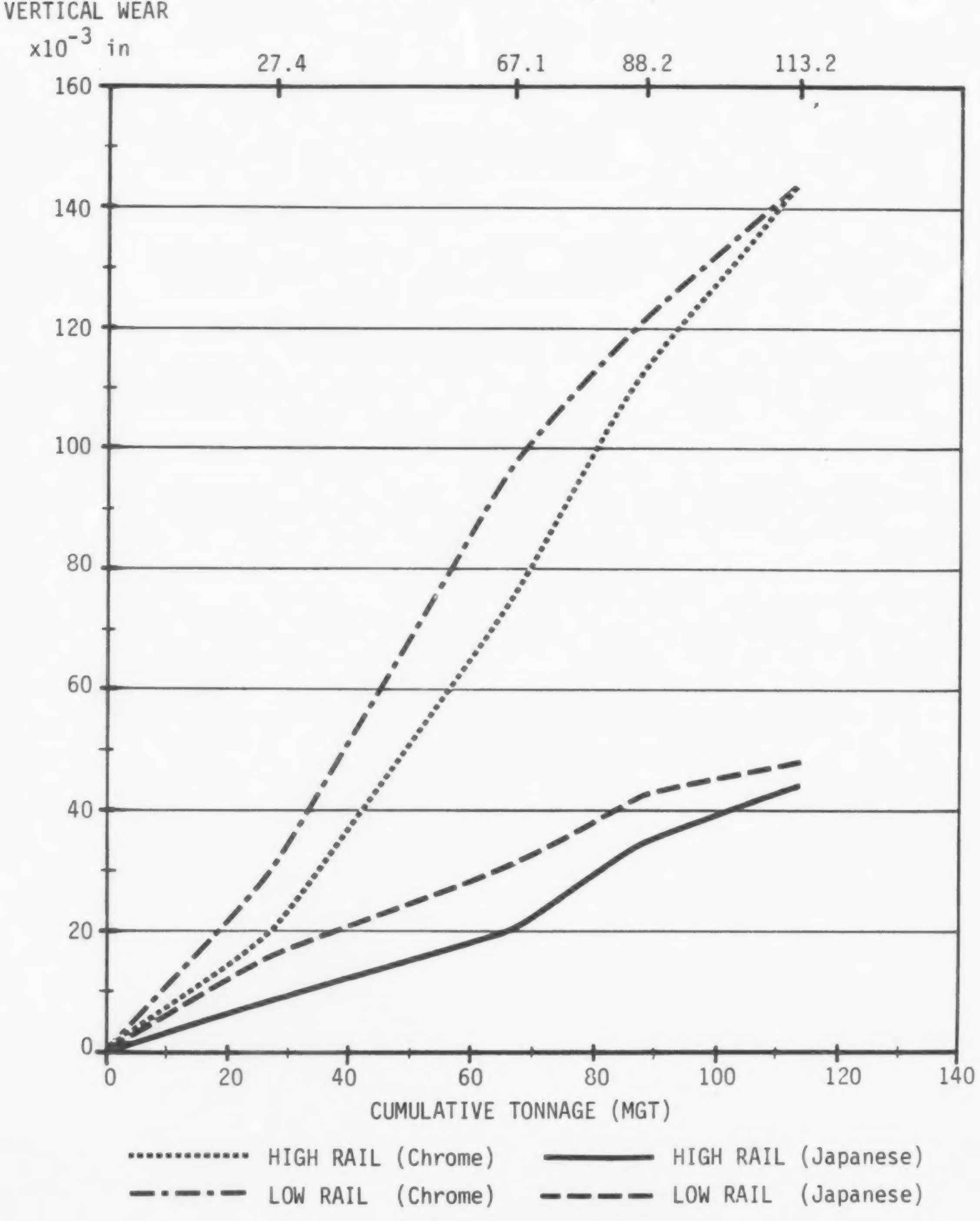


Figure A29: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #3

CHANGE-OVER POINT 4 (8.5°)

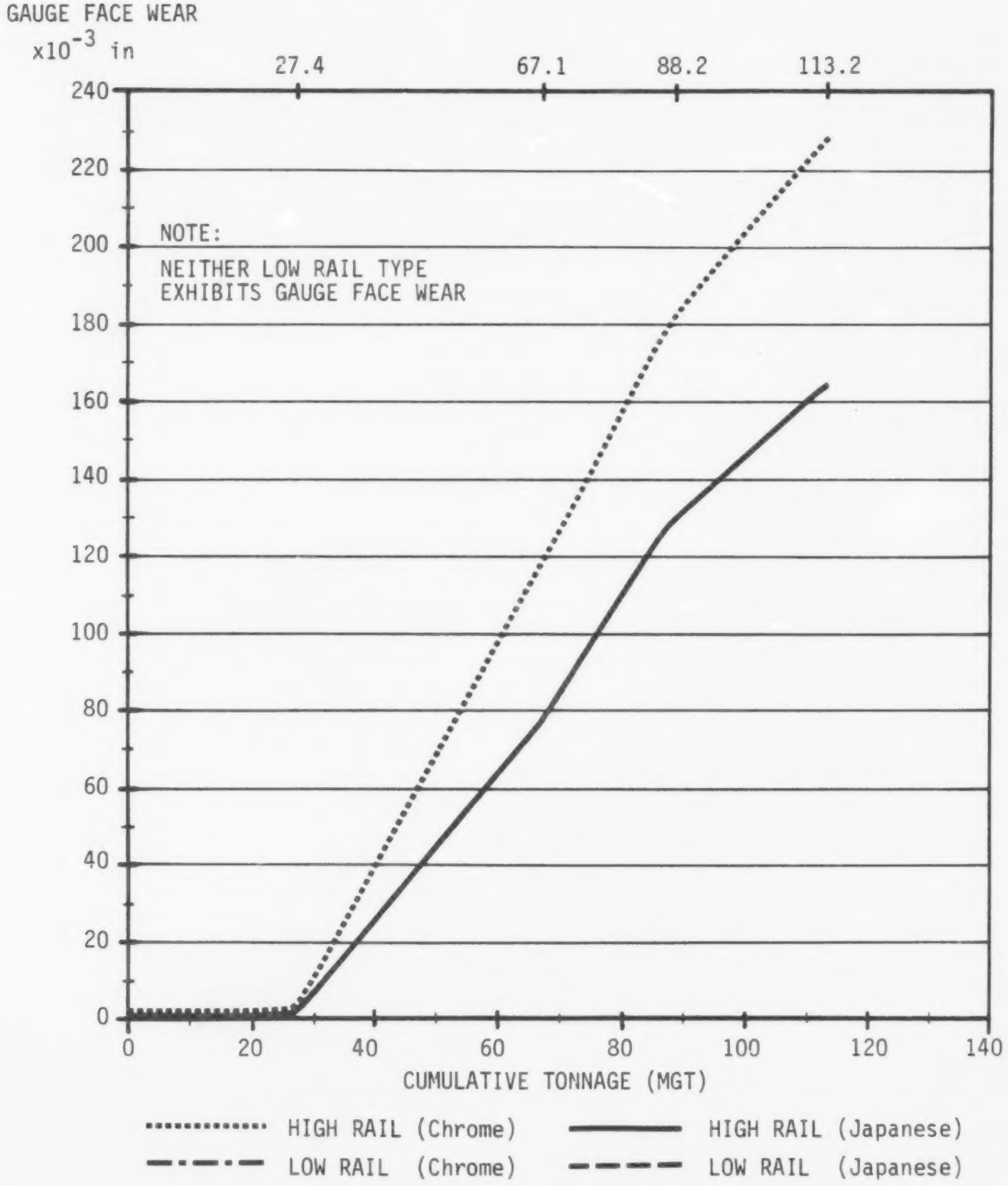


Figure A30: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

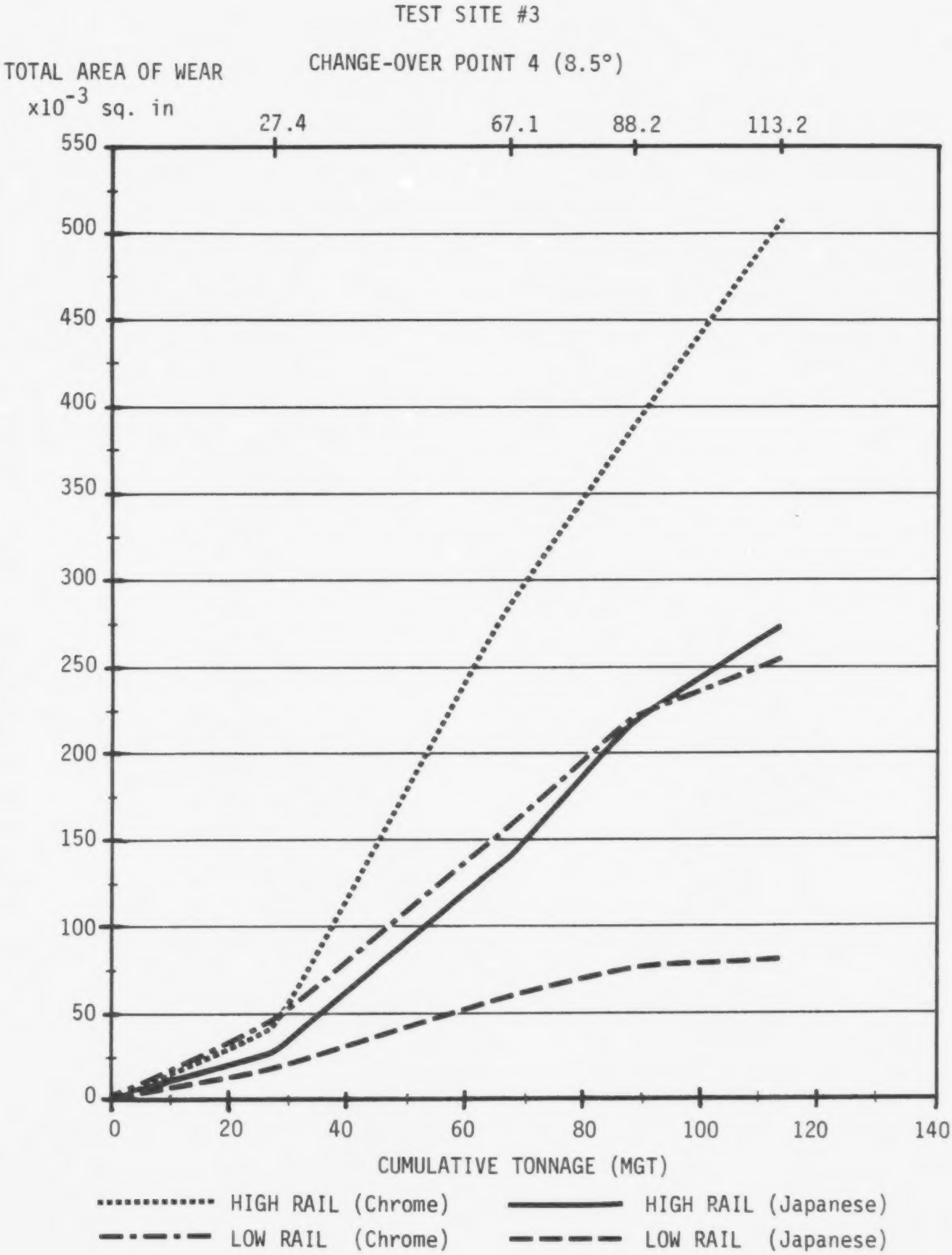


Figure A31: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8.5° Curve, For Algoma 1% Cr and Japanese Superrail

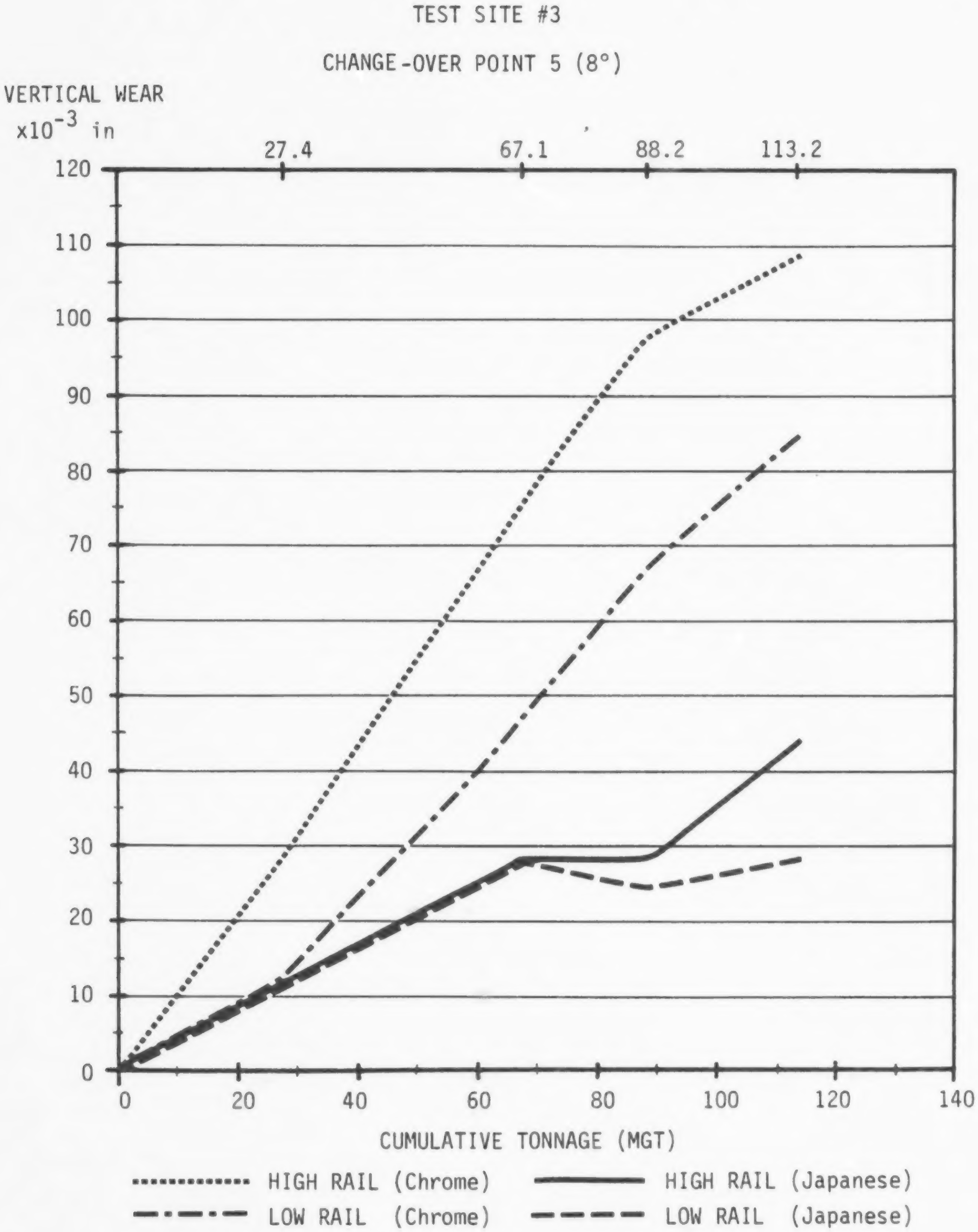


Figure A32: Vertical Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #3

CHANGE-OVER POINT 5 (8°)

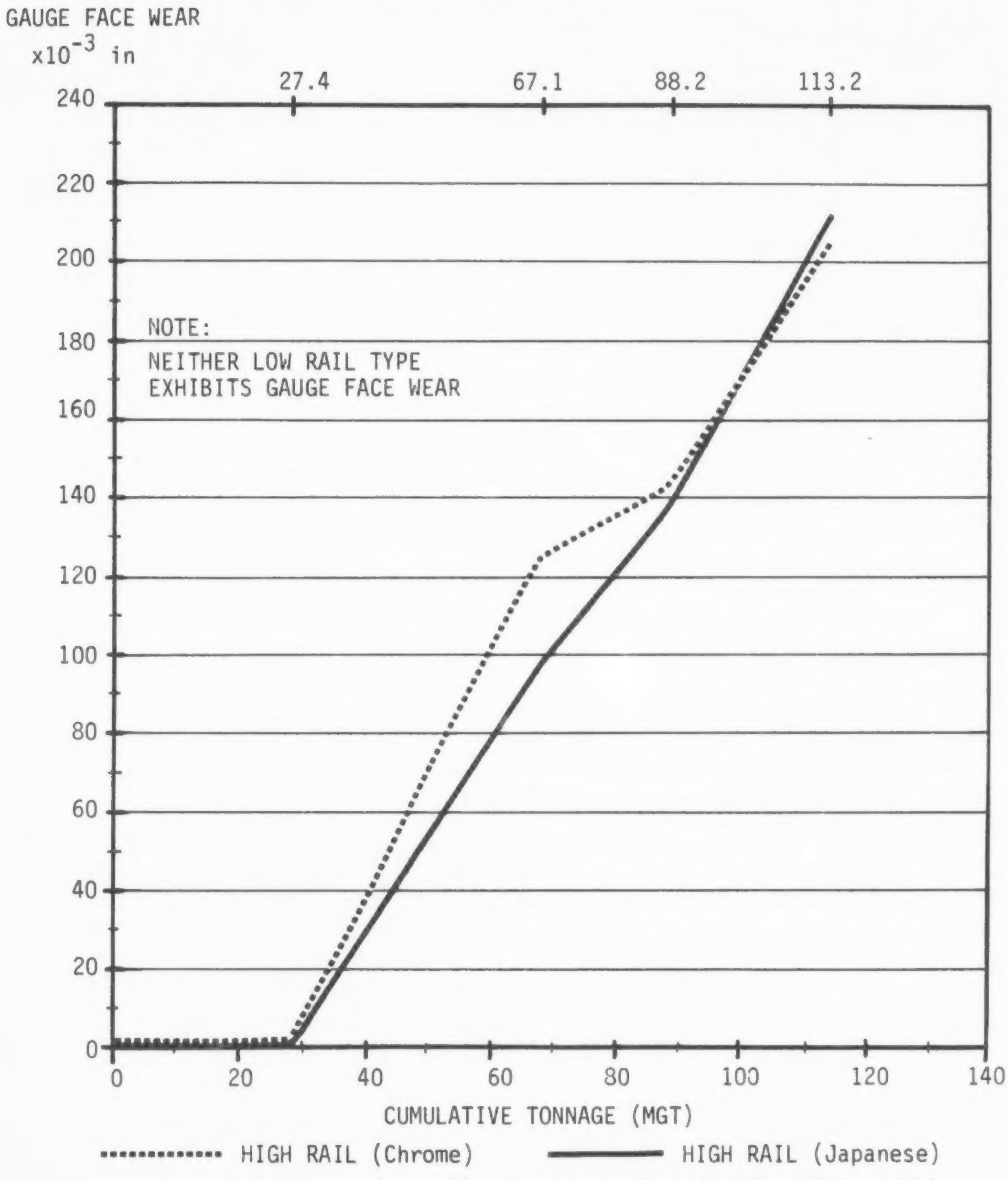


Figure A33: Gauge Face Wear Pattern Comparison For High Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail

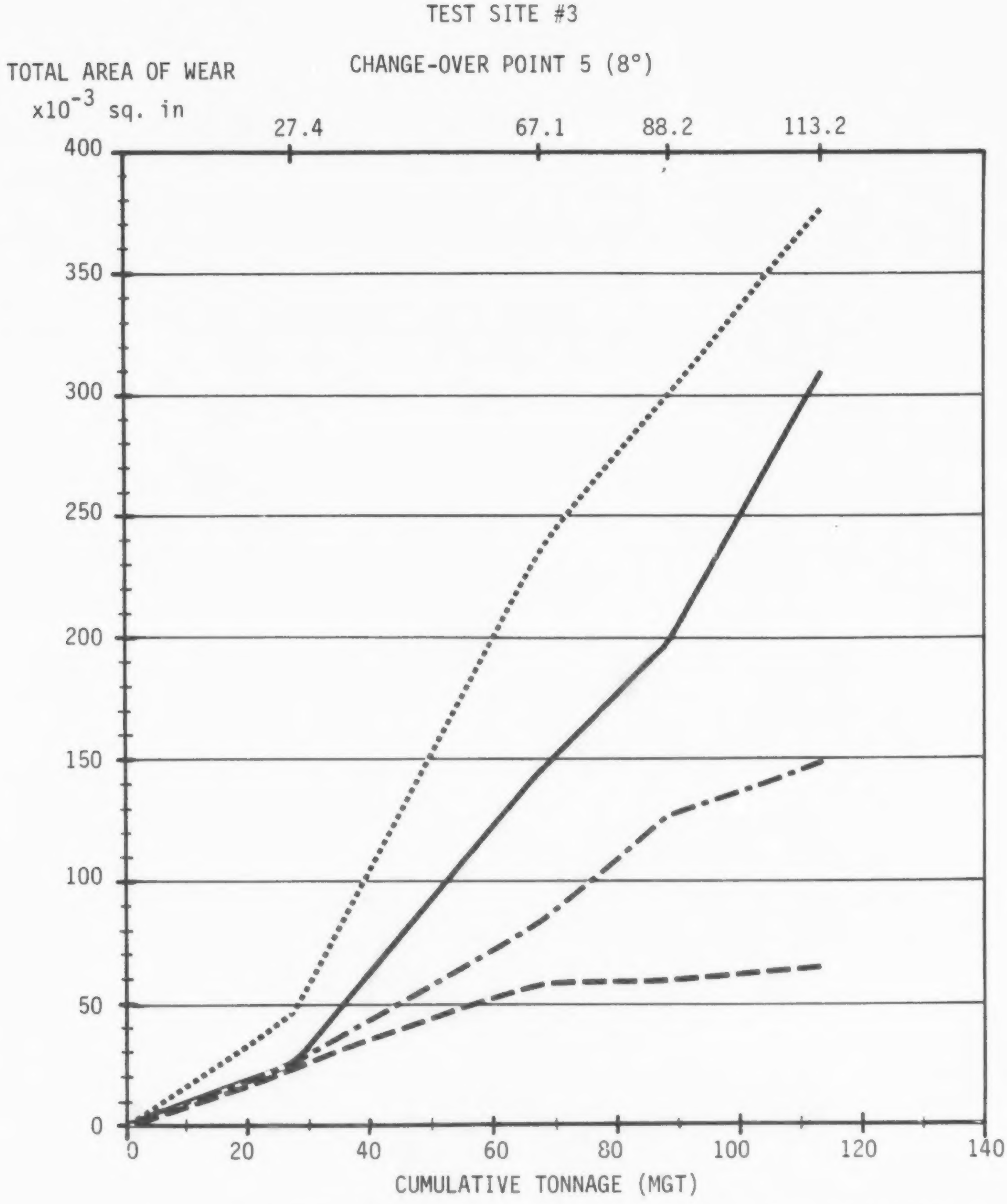
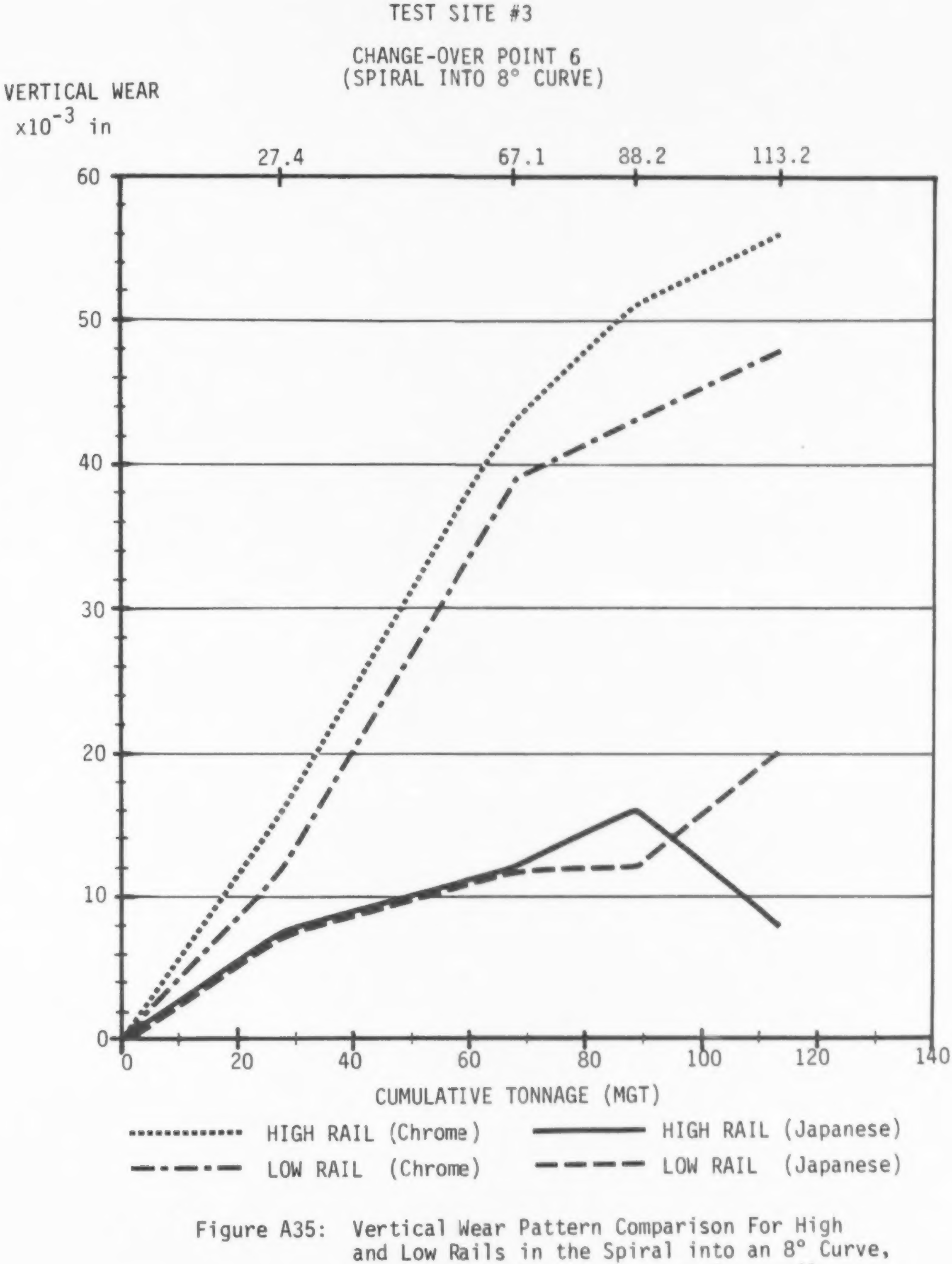


Figure A34: Total Head Wear Pattern Comparison For High and Low Rails in the Middle of the Fully Developed Section of an 8° Curve, For Algoma 1% Cr and Japanese Superrail



TEST SITE #3

CHANGE-OVER POINT 6
(SPIRAL INTO 8° CURVE)

Figure A35: Vertical Wear Pattern Comparison For High and Low Rails in the Spiral into an 8° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #3

CHANGE-OVER POINT 6
(SPIRAL INTO 8° CURVE)

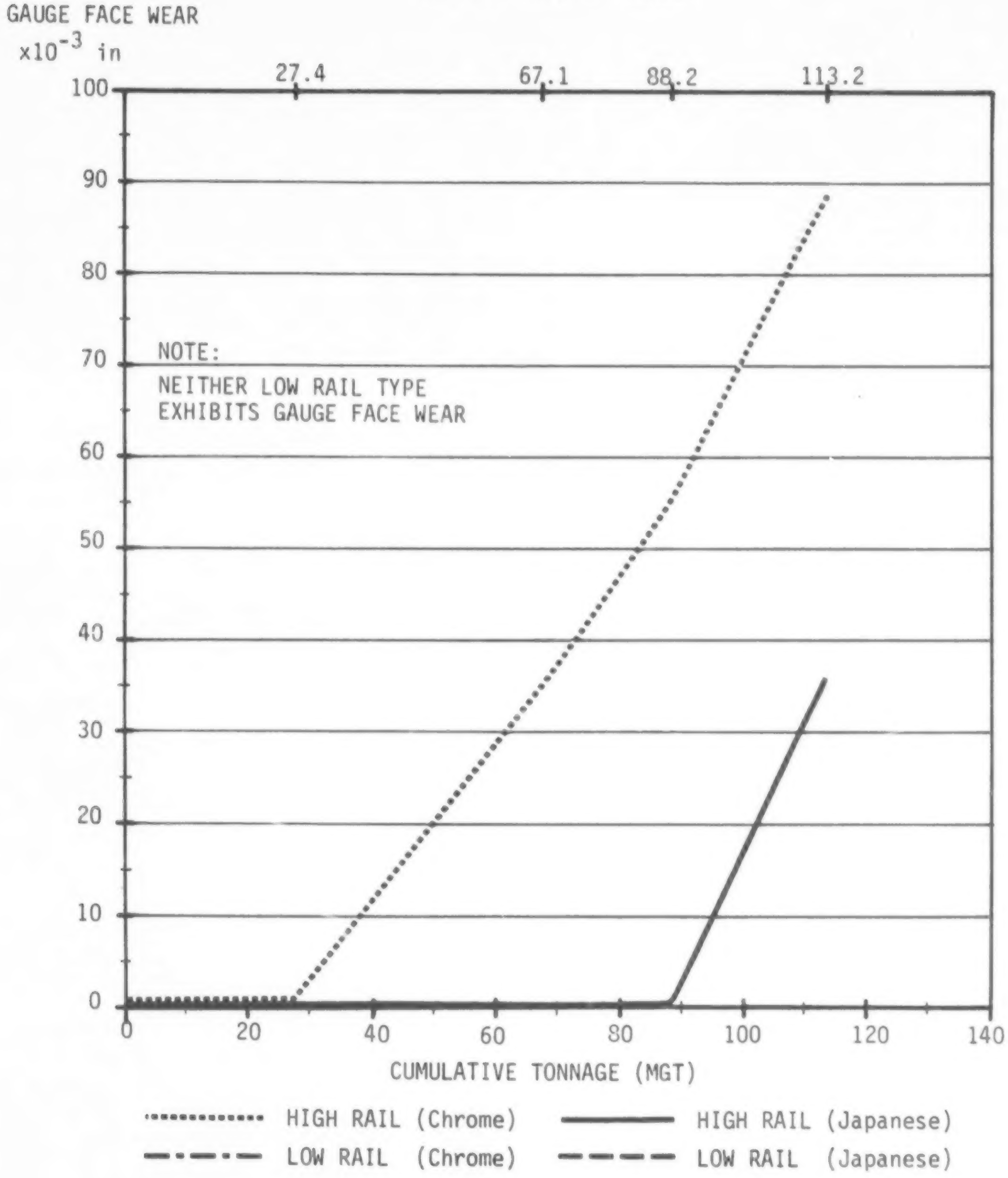


Figure A36: Gauge Face Wear Pattern Comparison For High Rails in the Spiral into an 8° Curve, For Algoma 1% Cr and Japanese Superrail

TEST SITE #3

CHANGE-OVER POINT 6
(SPIRAL INTO 8° CURVE)

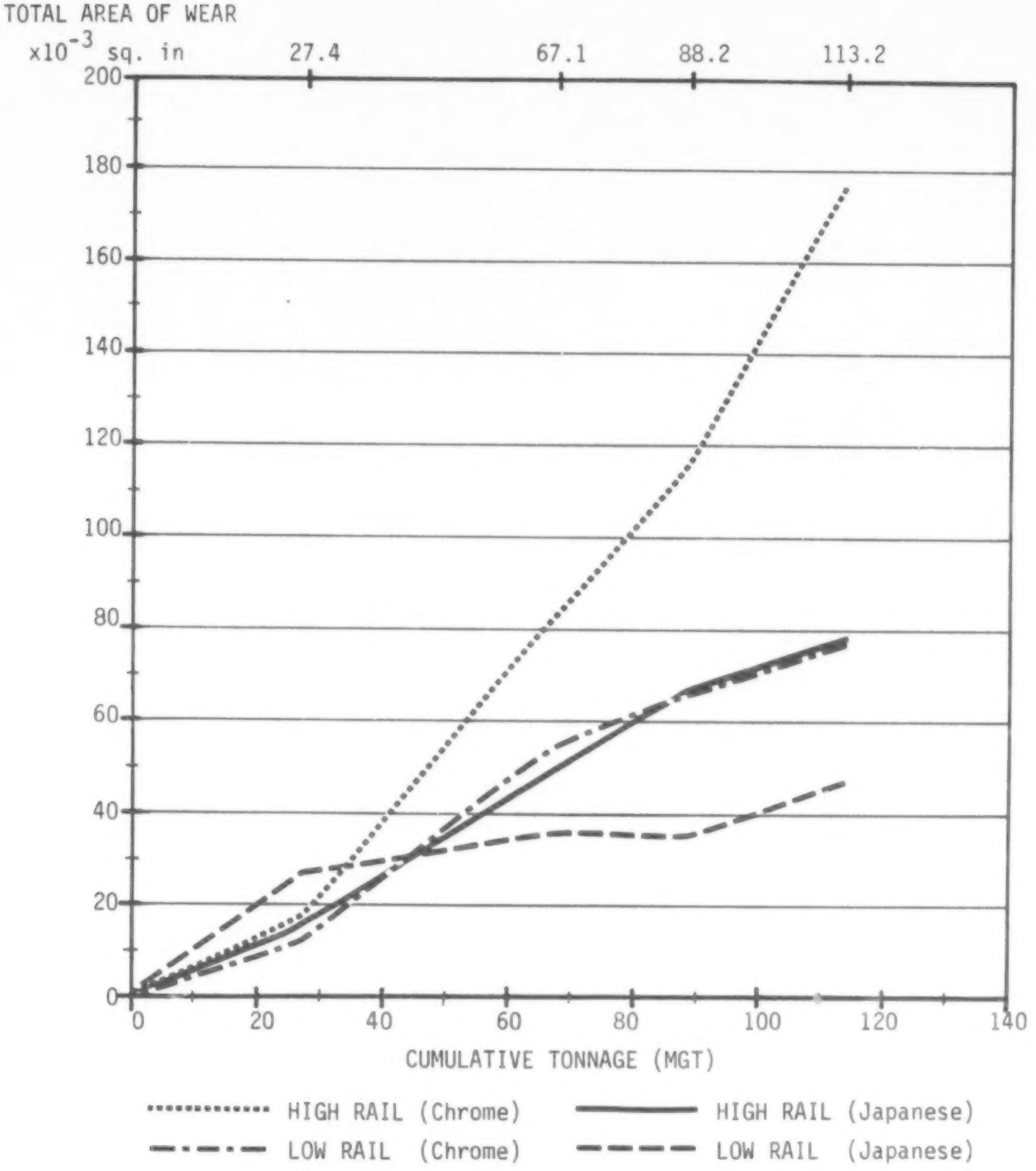
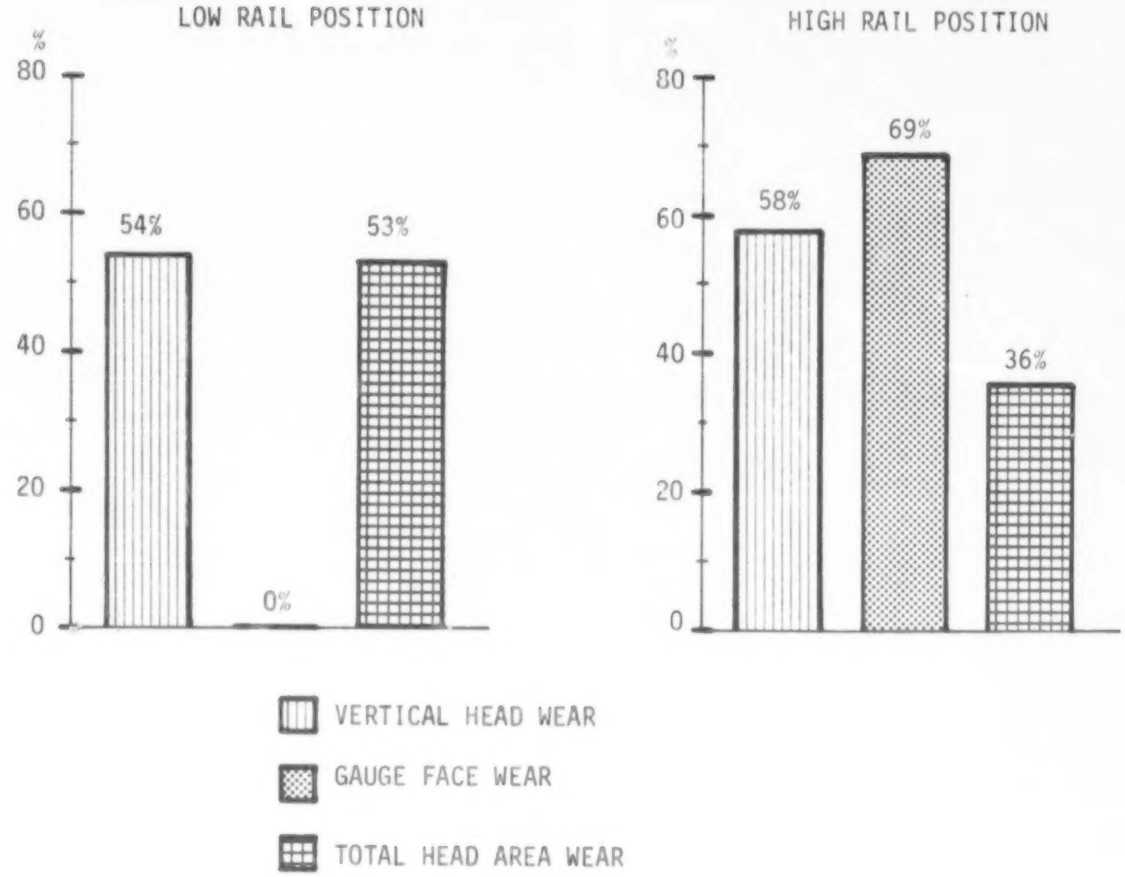


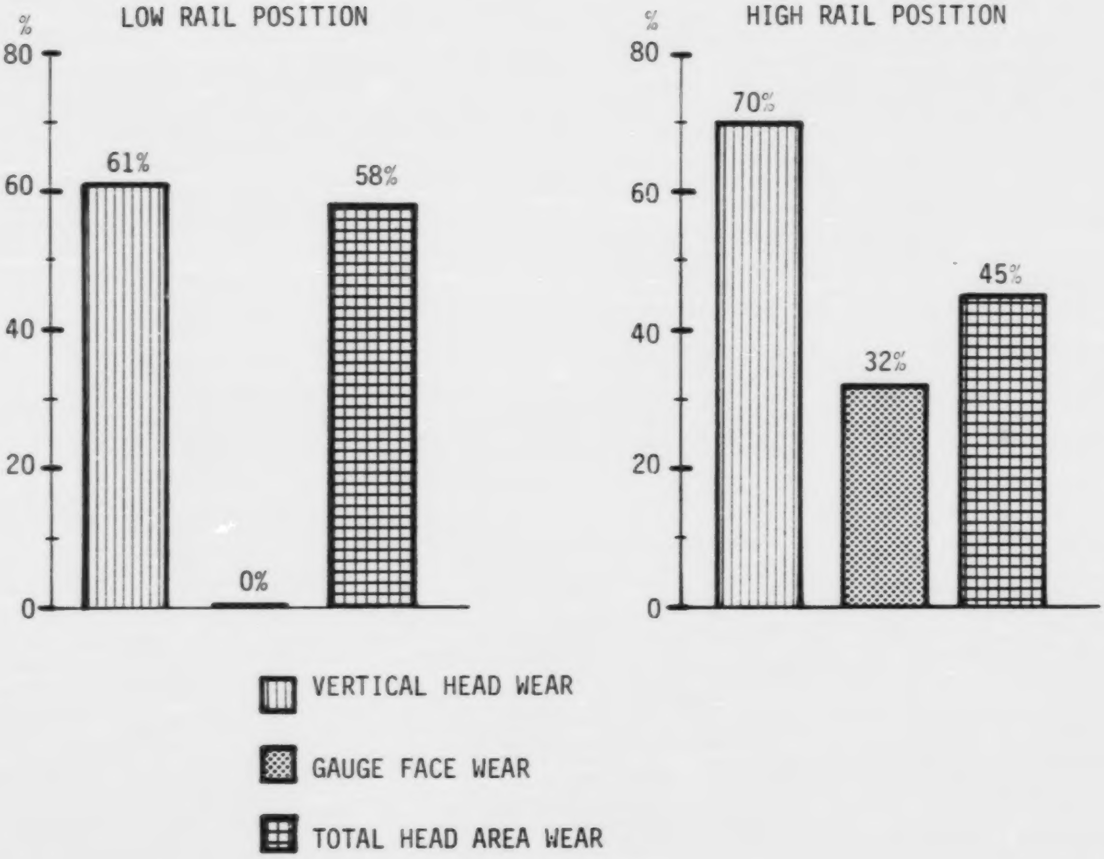
Figure A37: Total Head Wear Pattern Comparison For High and Low Rails in the Spiral into an 8° Curve, For Algoma 1% Cr and Japanese Superrail

Figure A38: % Reduction in Vertical, Gauge Face and Total Head Wear Achieved by the Japanese Superrail, in Relation to Algoma 1% Cr Rail, For Test Site #2*



* - average values based on February, 1985 cumulative wear profile comparisons of both rail types for all change-over points in test site #2 -- minimum 0.004 inch difference in vertical and gauge face wear specified to constitute significant difference, 0.031 sq. inch difference specified for total head wear.

Figure A39: % Reduction in Vertical, Gauge Face and Total Head Wear Achieved by the Japanese Superrail, in Relation to Algoma 1% Cr Rail, For Test Site #3*



* - average values based on February, 1985 cumulative wear profile comparisons of both rail types for all change-over points in test site #3 -- minimum 0.004 inch difference in vertical and gauge face wear specified to constitute significant difference, 0.031 sq. inch difference specified for total head wear.

APPENDIX B

CONDEMNING LIMIT WEAR PATTERN COMPARISON BETWEEN ALGOMA 1% CHROME AND JAPANESE SUPERRAILS

Table B1 summarizes the maximum limits of gauge face and vertical head wear for AREA 136-RE sections (see Reference 5), the 136-RE railhead closely approximates that of the Japanese Superrail.

Table B1

Maximum Rail Wear Limits: 136-RE Rail Section

Gauge Face Wear (in)	Gauge Face Wear (mm)	Vertical Head Wear at Centre Line of Rail (in)	Vertical Head Wear at Centre Line of Rail (mm)
0	0	0.688	17.5
0.125	3.2	0.625	15.9
0.250	6.4	0.625	15.9
0.375	9.5	0.469	11.9
0.500	12.7	0.375	9.5
0.625	15.9	0.313	7.9
0.688	17.5	0.281	7.1

The Algoma Cr and Superrail sections comprising test sites #2 and #3 all exhibit stable wear rates after 113.2 MGT (approximately two years service); however, these wear patterns were established under abnormal field conditions — no periodic maintenance as normally practiced. In order to predict relative lives of the two test rail types on the basis of cumulative wear, having wear data for only 113.2 MGT and under the given test conditions, certain assumptions must be made:

- test rails experience annual traffic of 60 MGT,

- grinding operations remove 0.040 in/1.0 mm from about the railhead each year (to conform with the present test format, 0.080 in/2.0 mm will be assumed to be removed after each approximately two-year period), and

- a cyclical wear pattern (see Figure B1), based on the stable wear rates established for each test rail section after approximately two years (113.2 MGT), will describe the manner in which the test rails wear after each grinding operation -- up to the point where the high rails are condemnable. Here the potential effects of rail transposition are discounted and relative wear lives are "determined" strictly on the basis of projected high rail wear lives.

Because a premium rail steel typically exhibits an initially (i.e. during the first 20-40 MGT in heavy-haul service) non-linear wear rate that is significantly higher than its subsequent stable wearing pattern (see Reference 1), the assumption of a cyclical wear pattern will lead to the projection of conservative values for rail lives — these projections are still valid, however, on a comparative basis between the two test rail types.

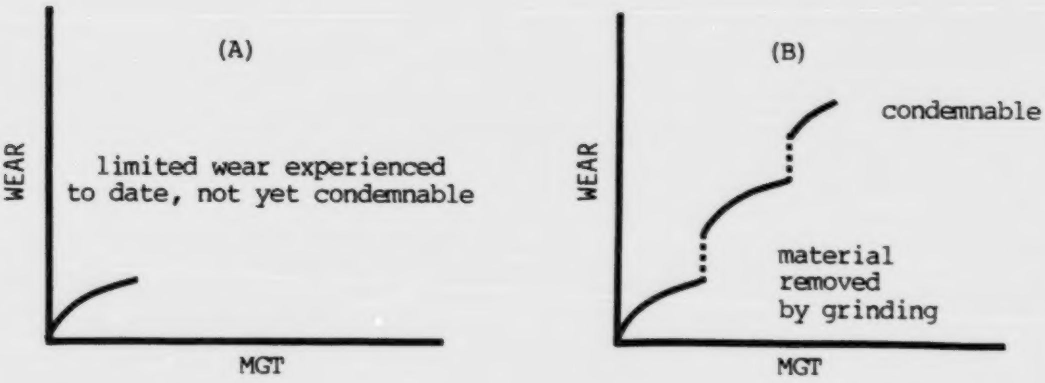

(A)
WEAR
limited wear experienced to date, not yet condemnable
MGT
(B)
WEAR
condemnable
material removed by grinding
MGT

Figure B1: Cyclical Wear Pattern Approach Employed to Estimate Relative Wear Lives of Test Rails

Under the given assumptions, and using the data contained in Tables 2, 3 and B1, high rail wear life projections were made. These projections are listed in Table B2.

Table B2

Wear Life Estimates for Comparable Algoma 1% Cr and Japanese Superrail Test Sections

Test Site	Change-Over Point and Degree	Projected Life of HCr*		Projected Life of HJ*		% Increase in Expected Life for Superrail Over Cr Rail
		MGT	Years	MGT	Years	
2	1, 3.5 Degrees	340	5.7	450	7.5	32
	2, 6.5 Degrees	340	5.7	730	12.2**	115
	3, 8.5 Degrees	280	4.7	450	7.5	61
	4, 4.5 Degrees	450	7.5	760	12.7	69
	5, 6.5 Degrees	310	5.2	430	7.2**	39
3	1, 8.5 Degrees	180	3.0	270	4.5	50
	2, 8.0 Degrees	225	3.8	340	5.7	51
	3, 8.5 Degrees	170	2.8	260	4.3	53
	4, 8.5 Degrees	225	3.8	340	5.7	51
	5, 8.0 Degrees	240	4.0	300	5.0	25
	6, spiral into 8.0 Degrees	340	5.7	560	9.3	65

*HCr/HJ refer to Algoma 1% Cr/Japanese Superrail sections located in the high rail position in the fully developed portion of a curve.

**The significant difference in projected wear lives between change-over points 2 and 5 (both 6.5 degree curves) may be explained by differences in track quality and grade (+1.3% vs -0.5% for change-over points 2 and 5, respectively). This emphasizes why wear values from different sites should not be quantitatively compared.

APPENDIX C

COMPREHENSIVE RAIL EVALUATION PROGRAM

A comprehensive program for the in-track evaluation of premium rail metallurgies would involve monitoring the resistance of these rails to wear, plastic flow and surface defect formation throughout their service lives under expected loading environments and maintenance practices. Such an approach would permit a bottom-line economic assessment of a new rail steel.

Significant variations in original rail head size can occur due to rolling tolerances; therefore, valid predictions of rail wear performance can only be made by measuring rail head profiles at each measurement point prior to traffic, and using these profiles with subsequent measurements to determine rail wear. To date, the effects of rail grinding and/or transposition on subsequent rail performance cannot be fully quantified; these factors are not included in rail evaluation test programs presently performed by the Planning and Research Department. The present practice has been to monitor test sections for wear and surface damage under very little maintenance, up until it was absolutely necessary to grind/transpose these rails. At such times, the rail evaluation program would be discontinued and the performance of the test rail determined relative to the standard Algoma 1% Cr rail. It is recognized that this is not a comprehensive approach towards the in-track assessment of a rail steel.

The field evaluation of rails can be influenced by track maintenance practices and, in particular, the re-profiling of rails by grinding. For example, grinding can influence the subsequent wear rates exhibited by two test rail types by removing different proportions of work-hardened material. Further, the progressive monitoring of rail wear (with no maintenance), so as to project relative service lives, is disrupted by the sudden large section changes produced by grinding. It is difficult to quantify the effects of the above two factors. If grinding is included in future rail evaluation test programs involving the Planning and Research Department, it will be necessary to measure rail profiles immediately before and after the grinding operation to quantify such effects. This approach would be technically superior to the method presently employed but would introduce practical scheduling difficulties. As well, there would be some inherent technical disadvantages associated with such an approach. For example, with the present test site format (i.e. a series of two alternating rail types, one of them a standard, within a section of sharp reverse curves) it could happen that one test rail type would require grinding while the other type would not require grinding. In this situation both rail types would be ground, and an inaccurate (overly severe) evaluation of the superior rail metallurgy would result.

It is suggested that an improved system of test sites (see Table C1) would include, along with the alternating rail type section(s) mentioned above, an additional two test sites -- approximately equivalent to one another. One of these additional sites would have the premium rail steel being investigated alone over one or two reverse curves; the second additional test site would consist of the standard Algoma 1% Cr rail alone. All of the above test sites would be ground when necessary. The alternating rail type section(s) would serve primarily for comparative wear evaluations between the two test rails, while the two additional test sites would be best suited for comparative through-life evaluations under normal maintenance. Progressive rail profiles would only have to be taken on the alternating rail type test site(s).

Table C1

Suggested System of Test Sites

Test Site	Description	Allowable Maintenance	Purpose
1	Series of two alternating rail types over several sharp reverse curves (present format)	Regular grinding	Monitor relative resistance to surface damage & comparative wear evaluation
2	Premium rail under study, layed over 1-2 reverse curves	Regular grinding & transposition	Comparative through-life evaluation of rail types under study
3	Standard Algoma 1% Cr rail layed over 1-2 reverse curves similar to those in test site 2 above		

The effects of rail transposition on subsequent rail performance are still more difficult to account for than are the effects of grinding. Established rail change-over points will generally be lost after rail transposition. Since the loading history of rail strongly influences its resistance to wear and fatigue, the relative performance of newly created measurement points at this stage could be misleading. The effects of transposition on extending rail lives could, however, be investigated on the two additional test sites proposed here.

In summary, through-life rail evaluation programs which include the effects of rail maintenance are recommended, but will require changes to the present test site format along with increased levels of monitoring.

IN-SERVICE EVALUATION OF ACCELERATED-WATER-COOLED (AWC) CARBON RAIL -- PRELIMINARY REPORT

K. Griffin

Research & Development
CP Rail

Report No. T-885-85
September, 1985

SUMMARY

An experimental head-hardened carbon rail (AWC carbon rail) produced by Algoma Steel was installed, together with Algoma 1% Cr rail and NSC Superrail, in a series of short, sharp, reverse curves on the Pacific Region of CP Rail in December, 1984. Using data obtained with the rail profilometer developed by the Planning and Research Department, the relative wear performance of the AWC carbon rail is to be evaluated. Qualitative field observations are also to be made periodically to evaluate the relative susceptibility of the AWC carbon rail to surface defect formation.

This preliminary report documents the characteristics of the test site and the measurement points contained therein. Insufficient data has been accumulated to allow for any definite conclusions regarding the relative wear performance of the AWC carbon rails. These AWC rails did exhibit a marked susceptibility to surface defect formation, with grinding being necessary to eliminate potentially hazardous shells and corrugations after only five months service. The resistance of these AWC carbon rails to surface defect formation is expected to improve following grinding.

Following each series of rail wear measurements and observations, an addendum to this report will be issued.

SOMMAIRE

Un rail expérimental à champignon durci par trempe, dit rail AWC, et un rail à 1 p. 100 Cr, tous deux réalisés par Algoma Steel ont été comparés au "Superrail" japonais NSC, sur une série de contre-courbes prononcées du réseau CP Rail, région du Pacifique, en décembre 1984. Les données fournies par le profilomètre étudié par le Service de planification et de recherche de CP Rail serviront à établir la tenue à l'usure de rail AWC par rapport aux deux autres. Des observations périodiques vont également être faites afin de déterminer la susceptibilité du rail AWC aux avaries de surface, relativement aux deux autres.

Le présent rapport préliminaire donne les caractéristiques du site d'essai ainsi que des points au droit desquels les mesures profilométriques seront faites. Les données acquises jusqu'ici ne permettent pas encore de déboucher sur des résultats définitifs concernant la tenue du rail AWC à l'usure, bien qu'il affiche une susceptibilité marquée aux avaries de surface après seulement cinq mois de service, écaillages et usure ondulatoire sévères à éliminer immédiatement par meulage. Il est possible toutefois que la résistance du rail AWC aux avaries de surface s'améliore par suite d'un meulage.

Un addenda sera ajouté au présent rapport après chacune des séries de mesures et observations prévues au programme.

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1.0 INTRODUCTION

Between 1975-80, the management of Algoma Steel recognized that the use of, and physical demands placed upon, premium rail steels were increasing. It was further realized that the mechanical properties that would soon be required of premium rails would be unattainable by existing alloying practice and that the Algoma 1.15% Cr alloy rail could soon be non-competitive on the world market.

With the intention of maintaining, and eventually increasing, their share of the premium rail market, Algoma Steel initiated a variety of studies involving different alloy metallurgies as well as heat treatment procedures to standard carbon rails. By 1980, it was concluded that no known alloying route could alone provide sufficient improvement in the mechanical properties of Algoma rails to compare with the best rail product on the market, which at that time was a head-hardened carbon rail from Japan. Conventional off-line heat treatment processes offered the best metallurgical potential for the production of a rail with improved mechanical properties, but there was insufficient productivity to warrant the expense of modern off-line heat treatment facilities. It was therefore decided that a novel, on-line, heat treatment process was necessary to economically produce a competitive premium rail; this novel approach is the Accelerated-Water-Cooling (AWC) process (see Reference 1).

It is generally acknowledged that the best premium rails on today's market are low alloy, head-hardened, rails from Japan (eg. the NSC Superrail). Algoma Steel's stated goals are to upgrade their overall steel and rail processing capabilities, and to produce a commercially viable AWC alloy rail (AWC-340) at least equivalent to the Superrail. Algoma Steel intends the AWC-340 rail to supersede the use of their premium Cr rail and believes these goals can essentially be reached within 1-2 years.

As part of Algoma Steel's plan to develop the AWC process and an AWC alloy rail, it was decided to first develop an AWC carbon rail having mechanical properties approaching those of the Superrail and then to use knowledge so gained to develop an AWC alloy rail (AWC-340) of comparable strength and weldability to the Superrail. In early 1985, such AWC carbon rails were installed in CP track along with Algoma 1% Cr and NSC Superrail sections in order to obtain in-service comparative wear data under 100-ton unit train service. It was soon recognized that AWC carbon rails were inadequate for this service; the properties achievable using the AWC process on standard carbon rail are limited and do not approach those of the Superrail -- or even the existing premium Cr rail. This stage has since been passed over and Algoma Steel is now concentrating on developing an alloy metallurgy directly suitable for the production of AWC-340 rail.

There is a significant U.S. market for a minimum 300 BHN rail. The AWC carbon rail presently in CP track, although inadequate for 100-ton unit train service, would easily meet a minimum 300-BHN requirement. Algoma Steel has requested that this AWC carbon rail be monitored on a periodic basis for cumulative wear and surface defect formation; they now regard the present program as an accelerated test aimed principally at identifying any gross problems arising from the AWC process, as well as an accelerated evaluation of a "minimum 300-BHN AWC carbon rail".

There are certain short-comings associated with an accelerated test program such as this. The load spectra experienced in the present program will be very different (i.e. more severe) than that which would be encountered in the U.S. case. For both wear and surface defect formation, a small number of heavy wheel loads can be far more damaging to the rail than a larger number of lighter loads (see Reference 2). As such, extreme care should be taken in extrapolating the performance of the AWC carbon rail under CP service conditions to those which will be encountered in the U.S.

2.0 TEST SITE AND MEASUREMENT POINTS

Details of the physical and metallurgical properties of the Algoma 1% Cr rail and the NSC Superrail have been given previously (see Reference 1). A comprehensive metallurgical evaluation of the AWC carbon rail presently in track has not been performed -- this rail (and the AWC process) is still in the development stage. Limited testwork was performed by CP Rail on the AWC carbon rail prior to its installation, and revealed:

- significant variations in rail surface hardnesses with values ranging from 313 up to 387 BHN in areas within 2 inches of rail ends,
- a soft, shallow (0.10 inch), surface layer in which hardness increases from surface values in the 310-330 BHN range to minimum 340 BHN core values, and
- an outer 0.01 inch layer about the rail head which exhibits a bainitic structure -- the remainder of the 0.10 inch surface layer consists of various mixed microstructures while the core structure of the rail head is predominantly pearlitic.

The AWC carbon test rails were installed, along with the NSC Superrail and Algoma 1% Cr rail sections, at MP 50.5 on the Thompson Subdivision in December, 1984. A permanent 20 mph slow order has been in effect at this site since the installation of the test rails because of recent landslide activity.

In May, 1985 the Planning and Research Department was first asked to monitor the performance of the AWC carbon rail relative to the NSC and Cr rails. In June, 1985 the curvature, superelevation and track gauge characterizing the test site were measured and points of wear measurement were selected. This information is shown in Figure 1. Distances are given in terms of 31-foot stations, commencing at the eastmost Cr/NSC rail joint.

As of June, 1985 the AWC carbon rail test site had experienced 25.3 MGT. Information on the traffic passing over the test site was supplied by the Engineering Department, CP Rail.

3.0 DATA COLLECTION AND ANALYSIS

All profile data was collected with the rail profilometer (see Reference 2) developed by the Planning and Research Department, CP Ltd., and processed on the microcomputer in the department.

New profiles at the selected wear measurement points are not available; profile measurements were first taken in June, 1985 -- approximately five months after the installation of the test rails. It was therefore necessary to generate an average profile characteristic for each rail type and measure cumulative wear at each measurement point with respect to this "reference" profile (see Appendix A).

Further, excessive shelling of the AWC carbon rails necessitated grinding. Profile measurements were performed before and after the passage of the grinding train so as to subsequently distinguish material removal by grinding from that caused by wear and plastic flow.

For each profile comparison, three indices of relative wear are reported. These are: vertical head loss, loss at the gauge face and head area reduction. The vertical and gauge face losses are calculated in accordance with standard practice (see Reference 3), as shown in Figure 2. The area reduction calculations will consider as lost the material which has been removed from the rail head and material which has flowed outside the original profile. The resolution limit of the profilometer for vertical and gauge face wear is 0.1 mm (0.004 in), and approximately 10 mm^2 (0.016 in^2) for total head wear. For profile matching purposes, a difference of 0.2 mm (0.008 in) has been specified as the minimum difference required to constitute significant vertical and/or gauge face wear; 20 mm^2 (0.031 in^2) has been specified for total head wear comparisons.

4.0 PRELIMINARY RESULTS AND CONCLUSIONS

Table 1 summarizes the wear versus tonnage variations, along with the various amounts of material removed by grinding, for those representative wear measurement points selected for analysis.

AWC rails located in the fully developed sections of 8-9° curves have consistently experienced more wear than correspondingly located NSC Superrails and Algoma 1% Cr rails. The differences in the wear these rails exhibit are not large, however, since none of these rails have experienced substantial wear. Similarly, tangent track measurement points have experienced little wear to date. Additional wear measurements at higher tonnage passing levels are necessary to quantitatively distinguish the wear performance of these three rail types.

The AWC carbon rails exhibited a marked susceptibility to low rail shelling and corrugations (see Figure 3) -- this had been expected (see Reference 4) because of the characteristic 0.10 inch, mixed microstructure, surface layer about the AWC carbon rail. The AWC rails also experienced a longitudinal "tearing" in the center of the low rail running surface (see Figure 4), likely due to elongated, near surface, manganese-sulphide inclusions. These various surface defects necessitated the grinding of the entire AWC test site in June, 1985. It is expected that the resistance of the AWC rail to surface defect formation will improve following the removal of its soft, mixed microstructure, surface layer by grinding.

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2. "A Wheel/Rail Profilometer System", G. Izbinsky, H. Schrekinger and H. Soares, Planning and Research Department, Canadian Pacific Limited, Report No. T-805-84, February 1984.

3. "Standard Practice Circulars: Track", CP Rail.

4. "Algoma Head-Hardened Carbon Steel Rail (AWC-340 Rail)", internal memorandum, Planning and Research Department, Canadian Pacific Limited, December 1984.

Table 1

Wear Data for AWC Test Site, MP 50.5, Thompson Subdivision

Measurement Point and Description*	Wear Indice	Cumulative Tonnage (Tons x 10^6) 0 (Reference)	25.3 (Before Grind)	25.3 (After Grind)
3-HJ	Vertical (in)	0	0	0
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.021	0.055
4-LJ	Vertical (in)	0	0	0
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.002	0.028
5-HJ	Vertical (in)	0	0	0
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.023	0.046
6-LJ	Vertical (in)	0	0.012	0
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.010	0.021
7-HAWC	Vertical (in)	0	0	0
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.023	0.032
8-LAWC	Vertical (in)	0	0.059	0.055
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.092	0.110
9-HAWC	Vertical (in)	0	0	0.012
(8 1/2°)	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.038	0.069
10-LAWC	Vertical (in)	0	0.043	0.051
(8 1/2°)	Gauge Face (in)	0	0	0.024
	Total Area (sq. in)	0	0.071	0.124
11-Tangent AWC	Vertical (in)	0	0.020	0.028
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.037	0.068
12-Tangent AWC	Vertical (in)	0	0	0.012
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.003	0.064
23-Tangent AWC	Vertical (in)	0	0	0.020
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.001	0.055
24-Tangent AWC	Vertical (in)	0	0.031	0.043
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.055	0.119

Table 1 (Cont'd.)

Wear Data for AWC Test Site, MP 50.5, Thompson Subdivision

Measurement Point and Description*	Wear Indice	Cumulative Tonnage (Tons x 10^6) 0 (Reference)	25.3 (Before Grind)	25.3 (After Grind)
25-Tangent AWC	Vertical (in)	0	0	0.020
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.005	0.062
26-Tangent AWC	Vertical (in)	0	0.035	0.035
	Gauge Face (in)	0	0	0.020
	Total Area (sq. in)	0	0.056	0.120
13-LAWC (8°)	Vertical (in)	0	0.024	0.024
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.053	0.058
14-HAWC (8°)	Vertical (in)	0	0	0
	Gauge Face (in)	0	0.020	0
	Total Area (sq. in)	0	0.022	0.107
15-LAWC (8°)	Vertical (in)	0	0	0.016
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.003	0.046
16-HAWC (8°)	Vertical (in)	0	0.016	0.024
	Gauge Face (in)	0	0.016	0
	Total Area (sq. in)	0	0.047	0.095
17-LCr (8°)	Vertical (in)	0	0.035	0.039
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.081	0.114
18-HCr (8°)	Vertical (in)	0	0	0.012
	Gauge Face (in)	0	0.016	0
	Total Area (sq. in)	0	0.028	0.073
19-LCr (8°)	Vertical (in)	0	0.016	0.024
	Gauge Face (in)	0	0	0
	Total Area (sq. in)	0	0.020	0.063
20-HCr (8°)	Vertical (in)	0	0	0
	Gauge Face (in)	0	0.016	0
	Total Area (sq. in)	0	0.023	0.069

* The following abbreviations designate the rail position and type particular to each measurement point:

HCr/LCr	Algoma 1% Cr rail on high/low rail of curve
HJ/LJ	Japanese Superrail on high/low rail of curve
HAWC/LAWC	AWC carbon rail on high/low rail of curve

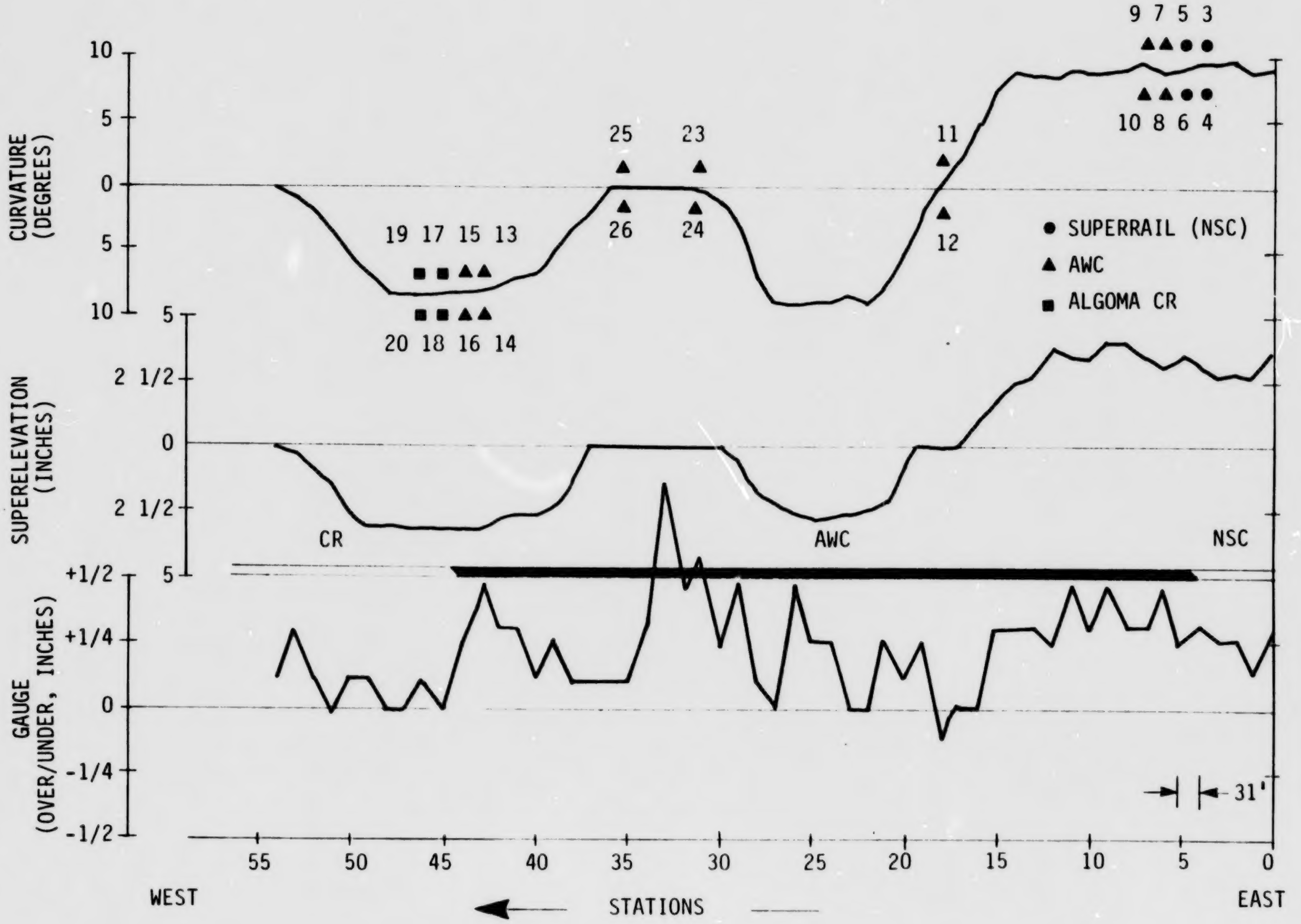


Figure 1: Curvature, Superelevation, Gauge and Location of Measurement Points for AWC Test Site at MP 50.5, Thompson Subdivision

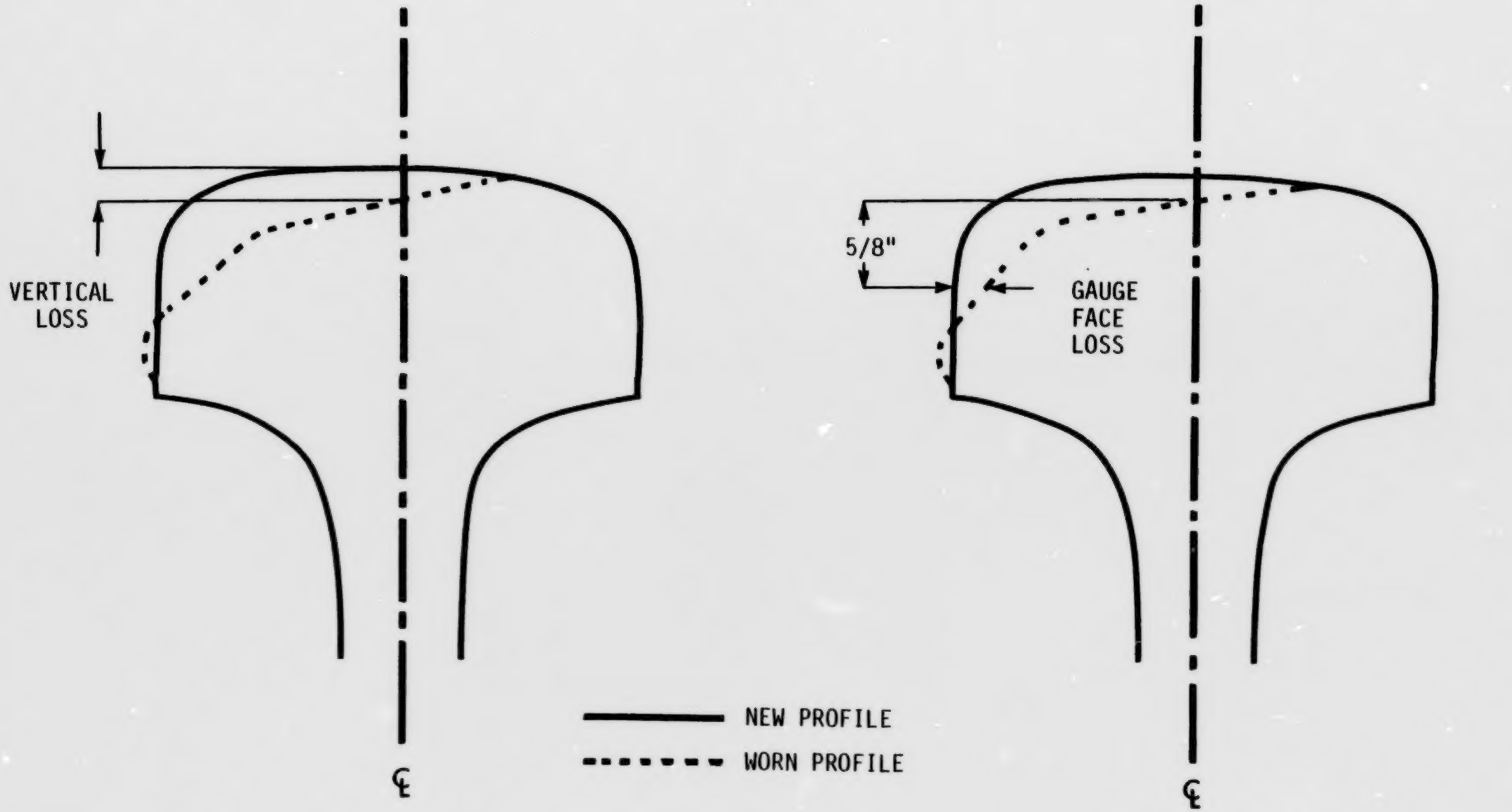

VERTICAL
LOSS
5/8"
GAUGE
FACE
LOSS
NEW PROFILE
WORN PROFILE
℄
℄

Figure 2: Definition of Vertical and Gauge Face Losses

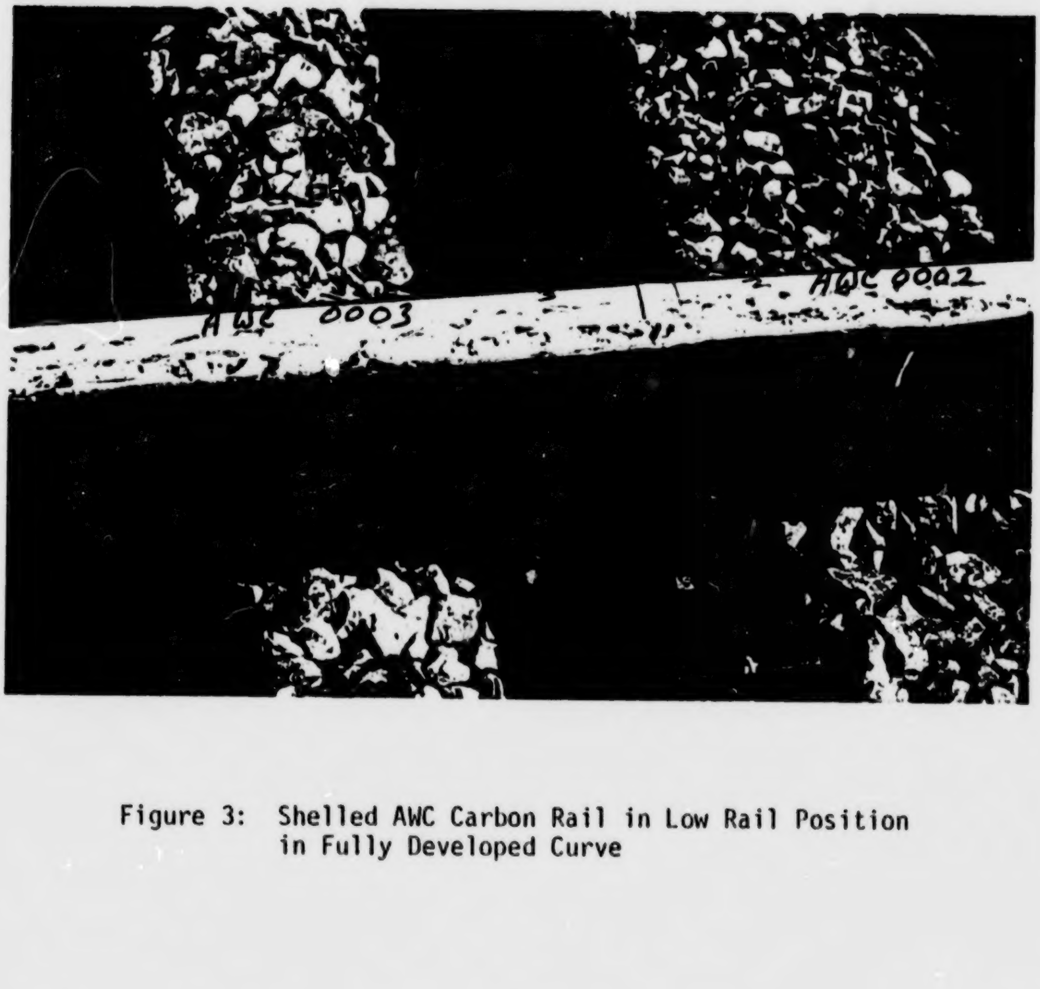

AWC 0003
AWC 0002

Figure 3: Shelled AWC Carbon Rail in Low Rail Position in Fully Developed Curve

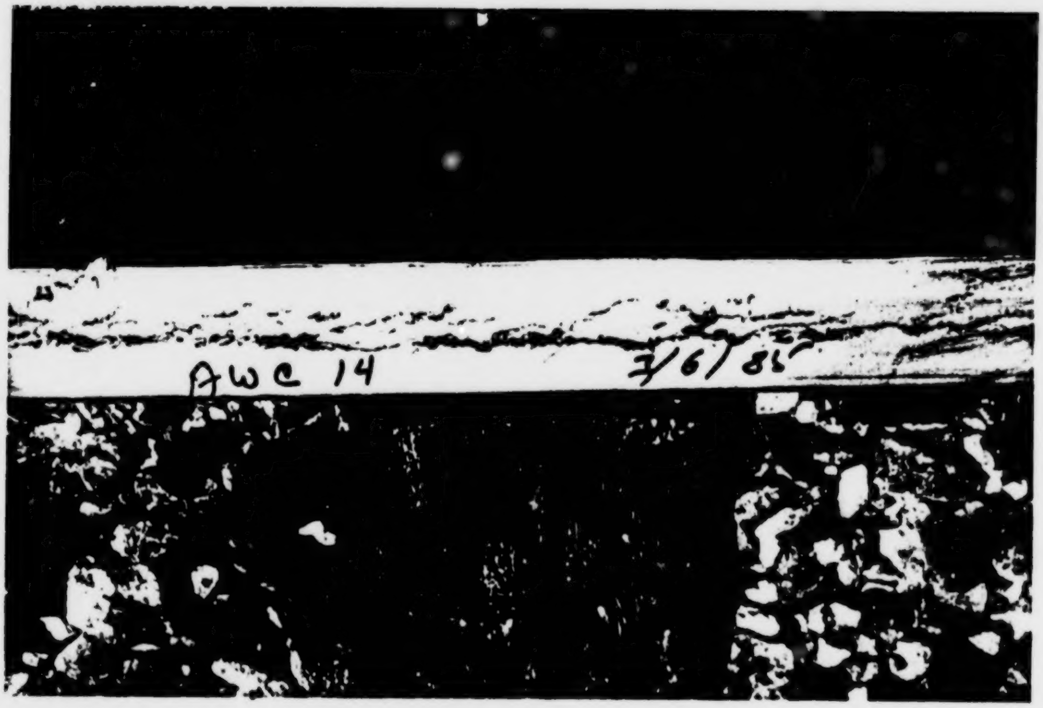


Figure 4: Longitudinal "Tearing" Occurring in Center of Low Rail Running Surface

APPENDIX A

CUMULATIVE WEAR MEASUREMENT PROCEDURE

A.1 Matching Profiles

All profiles obtained by measurement of sections of rail appear, after processing, in the same coordinate system. The rail profilometer does not, however, ensure that all profiles appear in exactly the same position for each measurement. Consequently the following technique is used to compare profiles:

1. The relative positions of the reference and worn profiles are viewed on a video monitor by mapping each point defining the profile to be viewed into a point (pixel) on the screen of the monitor.

2. The relative positions of the reference profile and the worn profile are changed by:

    a. translating the worn profile parallel to the x-axis

    b. translating the worn profile parallel to the y-axis

    c. rotating the worn profile about its center (the center of the worn profile is defined by taking the midpoint C of the line joining points A and B in Figure A1 below).

3. Two profiles are considered to be in the same position (matched) when the unworn portions of the worn profile coincide with the corresponding positions of the reference profile.

4. Normalization -- It should be noted that the reference profiles are normalized before the worn profiles are matched to them. This ensures that each profile is similarly positioned in the selected coordinate system before a profile comparison, maintaining a constant basis for relative wear measurements.

5. Resolution -- a 0.1 mm (0.004 in) translation and a 0.1 degree rotation of the worn profile are clearly visible on the video minotor.

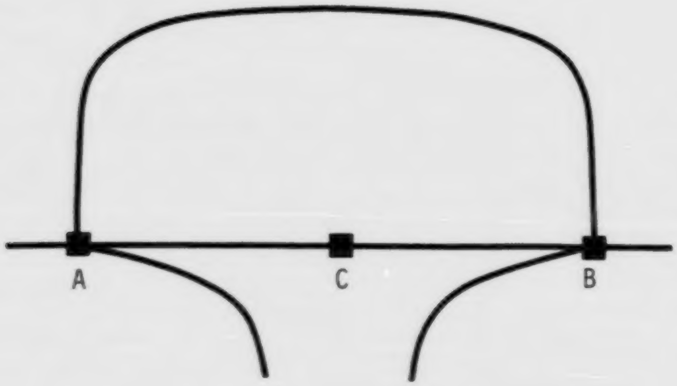


Figure A1: Definition of Center of Rail Head Profile

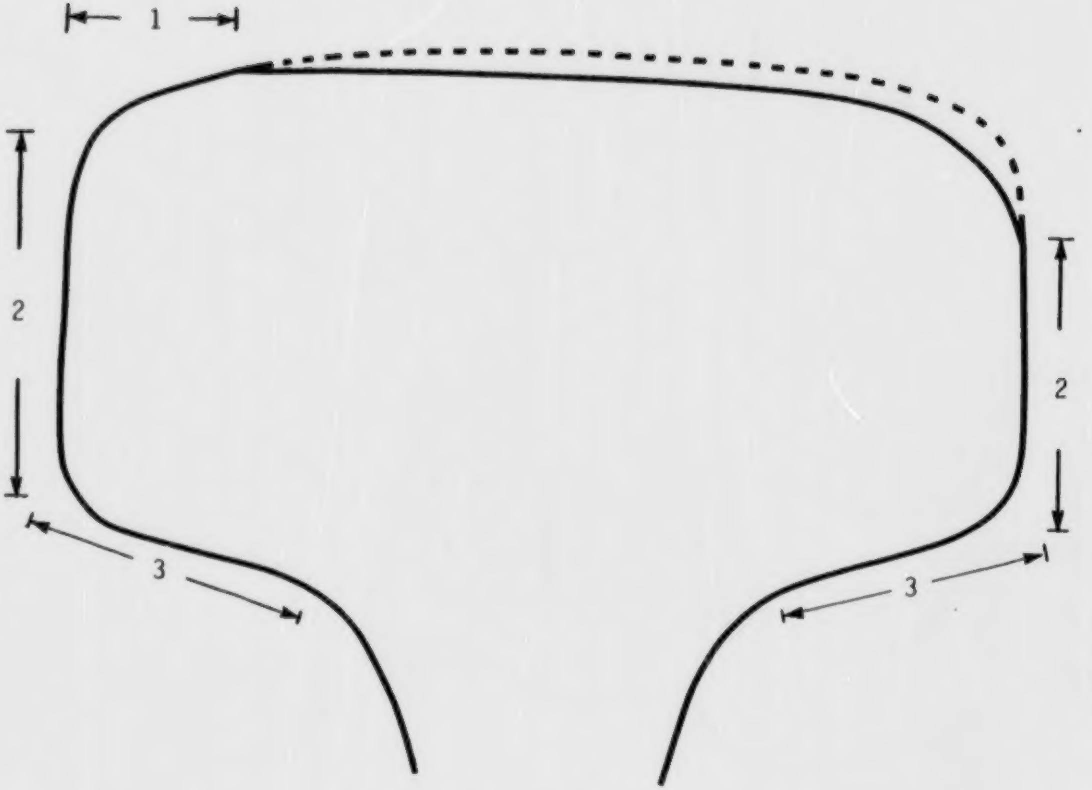
A.2 Creation of Reference Profiles

1. Profiles of unworn sections of Algoma 1% Cr and NSC Superrails were obtained (note that both the Algoma 1% Cr and AWC rail are rolled to similar 136-RE rail sections).

2. The profile of the unworn rail was superimposed on the profile of the worn rail obtained from the first measurement available. The method used is described in Section A.1 above.

3. The profile of the new rail was expanded or contracted parallel to the x-axis until its sides coincided with the unworn portions of the sides of the worn profile (see Figures A2 and A3).

4. The profile of the new rail was expanded or contracted parallel to the y-axis until the top and bottom coincided with the corresponding unworn portions of the worn profile (see Figures A2 and A3).



1. UNWORN TOP PORTION
2. UNWORN SIDE PORTION
3. UNWORN BOTTOM PORTION

Figure A2: Worn Profile Sample

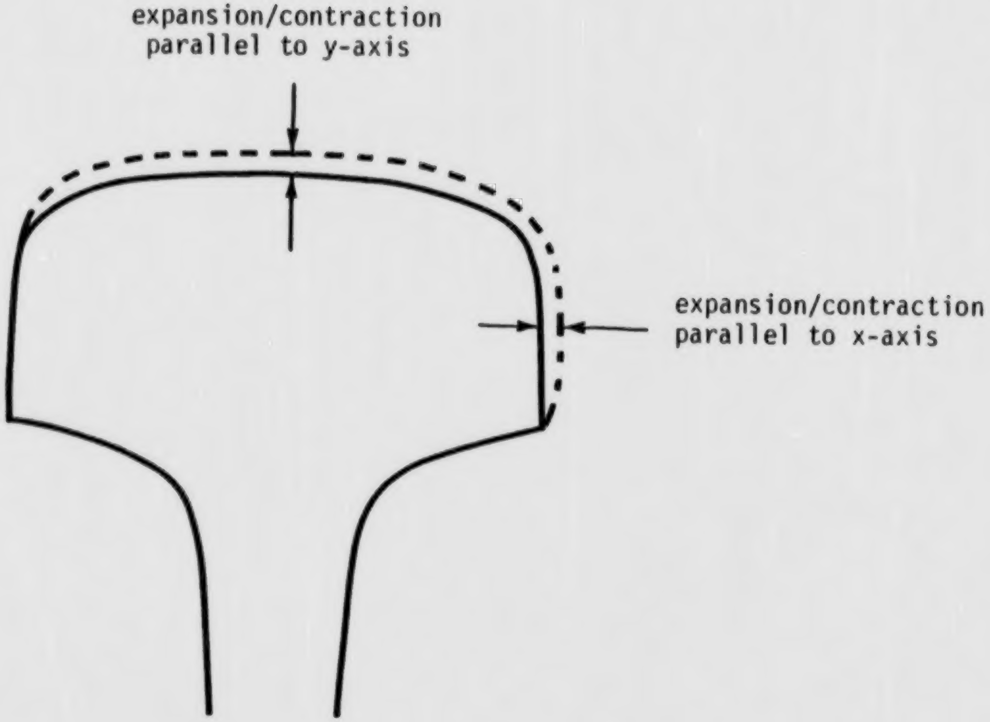

expansion/contraction
parallel to y-axis
expansion/contraction
parallel to x-axis

Figure A3: Reference Profile Sample
(typical expansion/contraction is 1%)

AWC-340 RAIL WELDING TRIALS
-- WELD ANALYSIS --

K. Griffin

Research and Development
CP Rail
Report No. T-899-85
December, 1985

SUMMARY

Head-hardened alloy rails (AWC-340) submitted by Algoma Steel are to be welded and installed, together with a premium Japanese rail, in a test site on the Pacific Region of CP Rail by late-November, 1985 for in-service comparative wear testing. However, an acceptable weld cycle for the AWC-340 rail first had to be established. To this end, tests were carried out at the Transcona Rail Yard between October 15-18, 1985.

Thirteen trial welds were produced involving a variety of weld cycles (distinguished by different preheat stages) and rail chemistries. The major difference between the weld cycles investigated was the amount of heat input during the preheat stage. The different rail chemistries examined encompassed the extreme range of the present AWC-340 rail chemistry ever likely to be submitted for welding. Selected trial welds were subjected to fracture tests and subsequent dissection and metallurgical investigation. Weld quality was judged on the basis of heat-affected-zone width, hardness contours and metallurgical structures exhibited across the weld zone, and general internal quality.

The most acceptable weld was produced with a weld cycle having a preheat stage of 7 preheats, 2.5 seconds power on and 5.0 seconds power off. It is recommended that this weld cycle be used to produce AWC-340 rail strings for the in-service comparative wear evaluation program.

SOMMAIRE

Des essais de résistance à l'usure du rail AWC-340 produit par Algoma Steel, fait d'acier allié soudé et à champignon durci par trempe, comparativement à celle d'un rail japonais de qualité ont eu lieu vers la fin de novembre 1985 sur un tronçon de CP Rail, région du Pacifique. Auparavant, un cycle de soudage satisfaisant devait avoir été trouvé pour le rail AWC-340 et, à cette fin, des essais ont été effectués dans la gare de triage Transcona du 15 au 18 octobre, 1985.

Treize éprouvettes représentant différents états physico-chimiques des rails on été produites selon divers cycles de soudage qui se distinguent les uns des autres par l'étape du préchauffage. La principale différence entre les divers cycles examinés a été la quantité de chaleur absorbée durant le préchauffage. Quant aux propriétés physico-chimiques du rail, elles représentent la gamme complète des propriétés métallurgiques que pourra emprunter ce rail au moment du soudage. Des éprouvettes choisies ont été soumises à des essais destructifs, suivi d'un examen métallurgique complet. La qualité de la soudure a été appréciée d'après des critères comme la zone thermiquement affectée, la dispersion des duretés, les caractéristiques métallurgiques de la zone de soudure et la structure interne générale.

Le cycle le plus satisfaisant a été celui qui comporte une étape de préchauffage faite d'une série de sept préchauffages, l'alimentation étant maintenue durant 2,5 secondes et arrêtée durant cinq. C'est ce cycle qui a été recommandé pour la constitution des longs rails soudés faits à partir du rail AWC-340 et devant être soumis aux essais de résistance à l'usure envisagés.

ACKNOWLEDGEMENTS

The Research Department acknowledges the contribution of personnel from the following organizations for their involvement and assistance during the course of the test program:

- Mr. W.A. Rieper of the Engineering Department of CP Rail for his significant contributions during all phases of the test program.

- Personnel of the Transcona Rail Yard for their cooperation during the welding trials.

- Personnel of Algoma Steel, Metals Research for their assistance in the preparation of metallurgical samples. Specifically, Mr. R. Ackert and Mr. M. Nott for their technical support in the analysis of the trial weld sections.

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1.0 INTRODUCTION

A series of welding trials was undertaken at the Transcona Rail Yard between October 15-18, 1985. The purpose of the trials was to establish an acceptable flash butt rail welding cycle for an experimental head-hardened alloy rail (AWC-340) produced by Algoma Steel. It is planned to install AWC-340 rails in a test site on the Pacific Region of CP Rail for in-service comparative wear testing in relation to a Japanese head-hardened alloy rail. Six 136 lb/yd welding trial rails were provided for study; details of these trial rails (see Table 1) are summarized below:

Table 1

Chemical Composition and Hardness of Welding Trial Rails

Rail No.	Algoma Heat No.	Algoma Rail Designation	Composition (%)						Hardness (BHN)
			C	Mn	S	P	Si	Cr	
1	5083C-4-7C	L73-X	.76	.77	.017	.022	.40	.71	349
2	6429B-1-8C	L80-X	.77	.86	.026	.027	.75	.58	369
3	5083C-1-6C	L65-X	.76	.77	.017	.022	.40	.71	347
4	6428C-2-3C	L125-X	.76	.90	.021	.020	.51	.76	363
5	5081C-1-2C	L128-X	.77	.77	.015	.018	.39	.73	342
6	5083C-2-8C	L82-X	.76	.77	.017	.022	.40	.71	370

To begin, five trial welds (see Table 2) were made using the weld cycle (see Table 3) previously determined for the NSC Superrail:

Table 2

Trial Welds Produced With NSC Superrail Weld Cycle

Weld No.	Rail No.'s Welded Together	
	Rail A	Rail B
1	1	2
2	2	3
3	3	4
4	4	5
5	5	6

Table 3

Established Welding Parameters for Japanese NSC Superrails

Parameter		Parameter	
initial burnoff	35 sec.	final flashing time	28 sec.
platen travel	1/4 in.	platen travel	1 7/8 in.
no. of preheats	9	forging time	3 sec.
preheat time current on	3 sec.	forging force	1200 psi
preheat time current off	4 sec.	forging platen	travel 7/8 in.
preheat travel	1/8 in.	weld upset	average 3/4 in.
current	1400 amps		

Preliminary examinations of welds 1-5 were conducted using Magnetic Particle inspection methods, as would normally be applied to production rail weldments. No significant indication of defects was detected.

A 58 inch section of rail no. 6, along with similar length sections of welds 1, 2 and 3, were then prepared and loaded in three-point bending.

The 58 inch section of rail no. 6 was loaded up to 350 tons without breaking. This rail section deflected +2 inches laterally and vertically with no obvious signs of cracking (see Figure 1). This was an acceptable response.

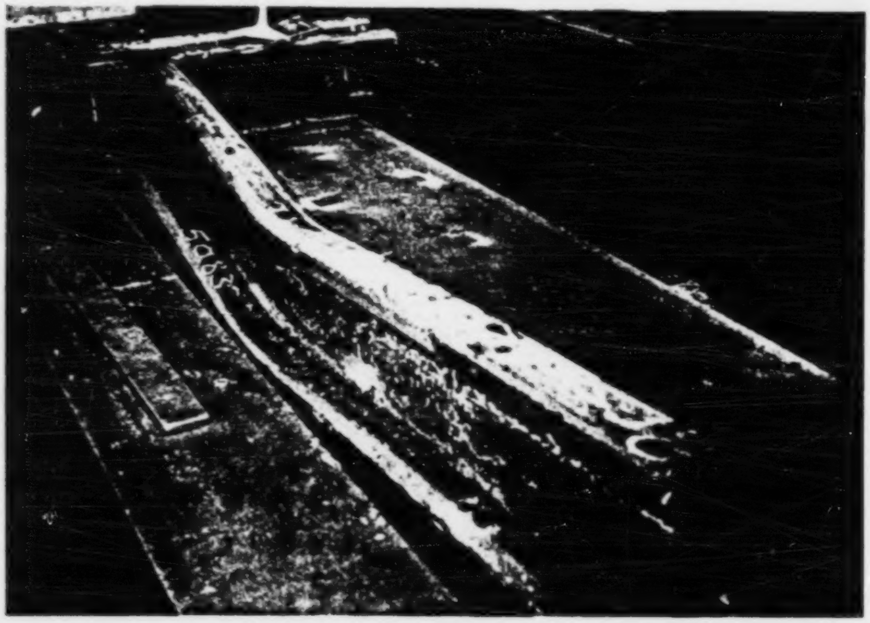
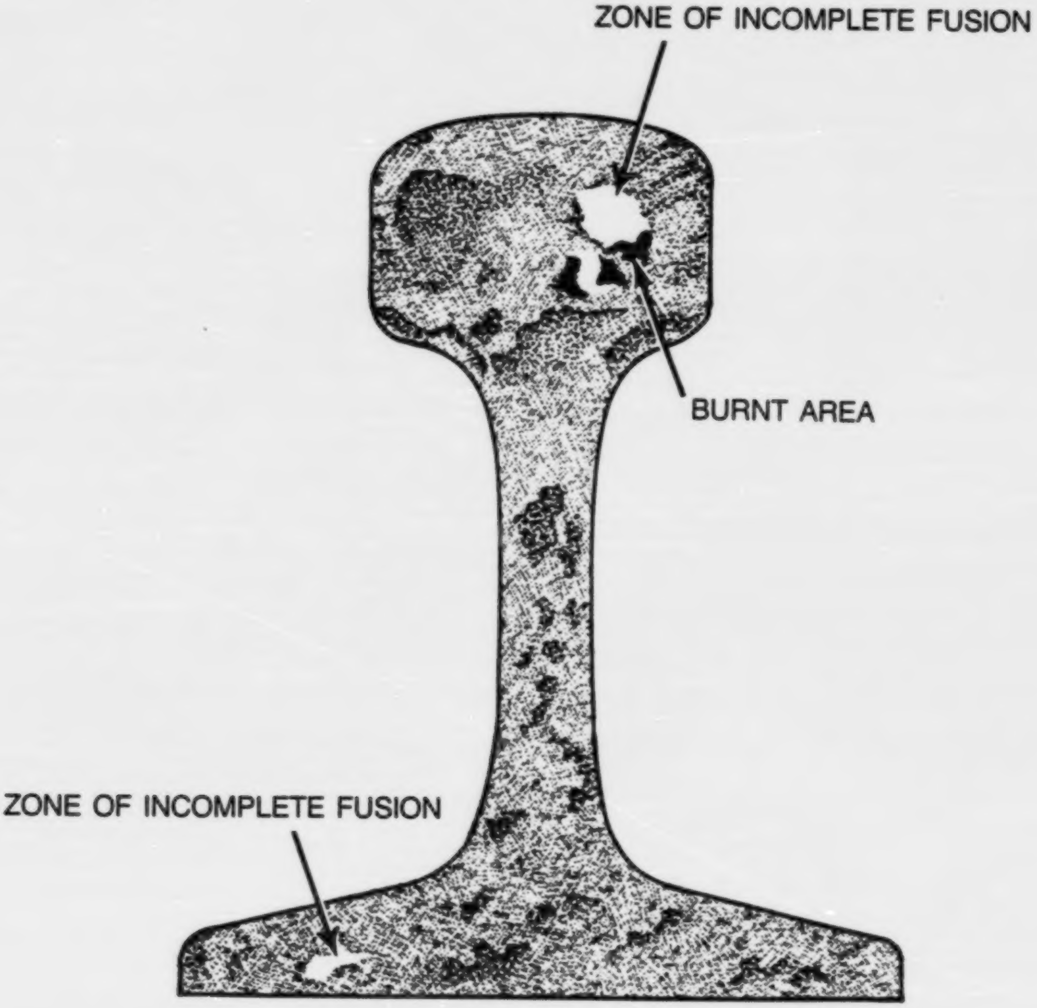


Figure 1: Deformation Experienced by Section of Rail No. 6 After Loading to 350 Tons in Three-Point Bending

The 58 inch sections of welds 1, 2 and 3 all fractured between 235-250 tons -- an acceptable level. However, subsequent examination of their fracture surfaces revealed burnt areas and zones of incomplete fusion (see Figure 2).


ZONE OF INCOMPLETE FUSION
BURNT AREA
ZONE OF INCOMPLETE FUSION

FRACTURE SURFACE FOR WELD No. 3

Figure 2

It was decided that the NSC weld cycle generated too much heat for the AWC-340 rails to properly accommodate, and that three different cycles (see Table 4) -- all having a lower heat input during the preheat stage than the NSC cycle -- would be investigated.

Table 4

Welds Produced With Trial Weld Cycles

Weld No.	Rail No's Welded Together		Weld Cycle, Preheat Stage
	Rail A	Rail B	
6	5	6	9 preheats, 2 1/2 sec. on, 4 sec. off
7	6	1	9 preheats, 2 1/2 sec. on, 4 sec. off
8	1	2	7 preheats, 2 1/2 sec. on, 5 sec. off
9	2	3	7 preheats, 2 1/2 sec. on, 5 sec. off
10	3	4	5 preheats, 3 sec. on, 4 sec. off
11	3	4	5 preheats, 3 sec. on, 4 sec. off

At the conclusion of these trials, 8 inch sections of welds 5-11 were prepared and sent to Algoma Steel for dissection and metallurgical investigation. A procedure for the evaluation of these welds was provided by CP Rail, and is attached as Appendix I to this report.

Welds 5, 6, 8 and 10 were immediately analyzed and the results of this analysis are presented in this report. Due to time constraints and the large amount of lab work required for complete weld analysis, welds 7, 9 and 11 will be analyzed at a slower rate and the results of this analysis will be available in a future report.

2.0 TESTING PROCEDURE AND RESULTS

Evaluation of welds 5, 6, 8 and 10 was done as specified by the CP Rail procedure -- Appendix I.

2.1 Macrostructural Evaluation

Maintaining the same notation used in the CP Rail procedure, sections (a), (b) and (c) were cut, ground, polished and etched.

2.1.1 Sections (a) and (b)

Figures 3-6 are macrographs of sections (a) and (b) for each of welds 5, 6, 8 and 10, respectively.

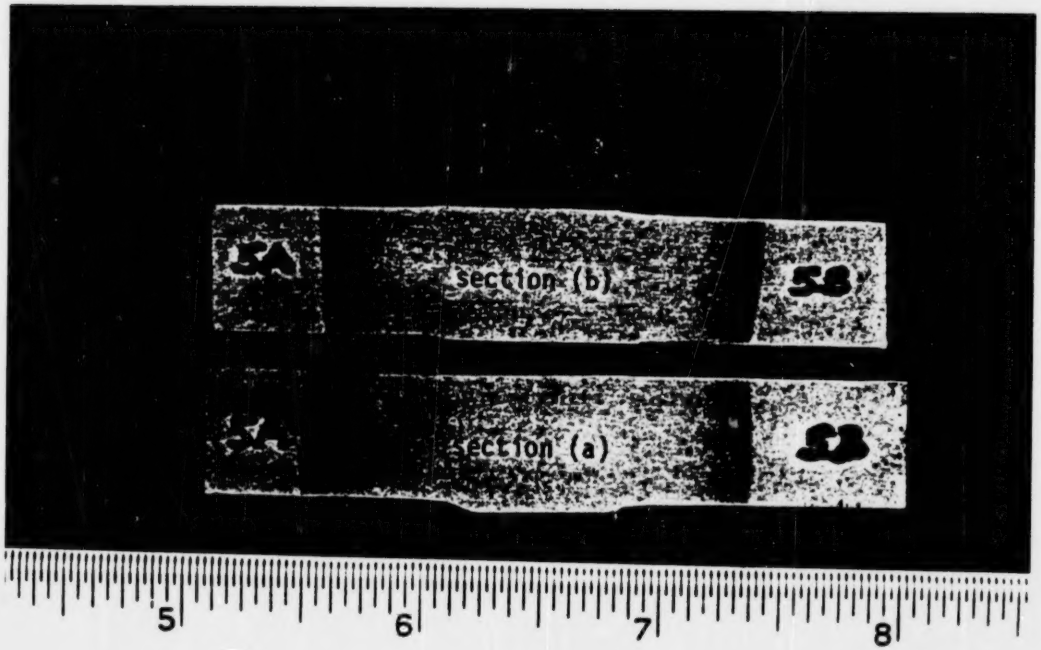
All weld samples exhibited a uniform heating pattern across the rail. The heat-affected-zones (HAZs), as demarked by the etch patterns, are of different widths from sample to sample. Welds 8 and 10 exhibit the narrowest, and therefore most desirable, HAZ patterns.

2.1.2 Section (c)

Figures 7-10 are macrographs of section (c) for welds 5,6, 8 and 10, respectively.

There is no evidence of significant welding related defects such as voids, cracks or lack of fusion in any of the examined macrographs. It was initially thought that incomplete fusion had occurred within the head area of weld no. 10 (see Figures 10 and 11) -- this was suggested by the dark area, located directly on the weld bond line (WBL), shown in Figures 10 and 11. Subsequent microscopic work (see Section 2.3) showed that this was, in fact, an area of highly refined pearlite with isolated bainite patches which had merely reacted to the HCl etch differently than the surrounding area. Hardness measurements taken within this dark area were in the order of 40-42 Rc (370-390 BHN) -- in accordance with a refined pearlitic structure.

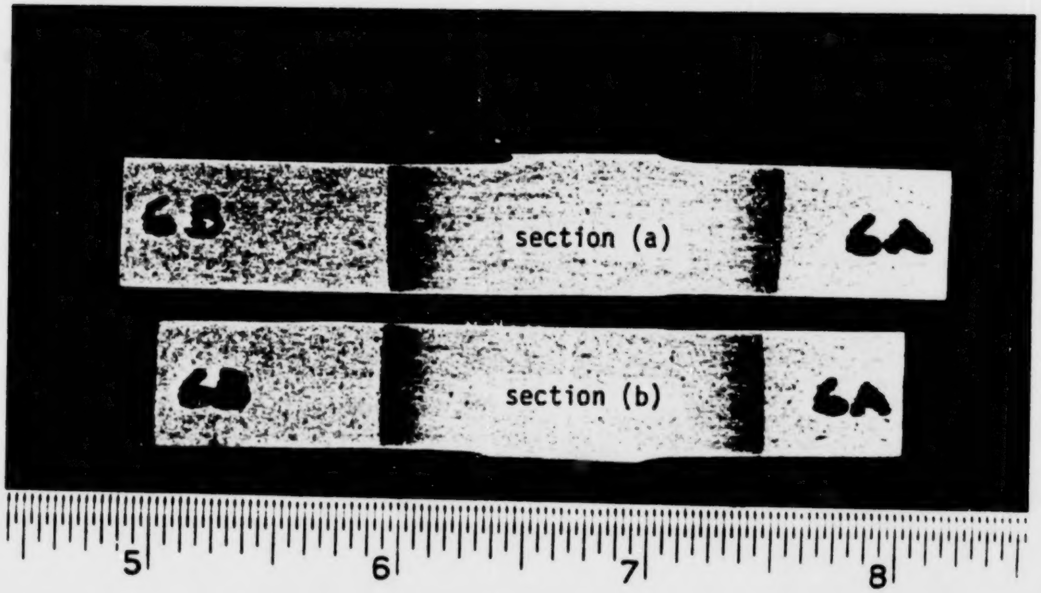
Weld no. 10, followed closely by weld no. 8, exhibits the narrowest and most desirable HAZ pattern of the examined weld samples.


5A
section (b)
5B
5A
section (a)
5B
5
6
7
8

maximum
width of HAZ

section (a) - 0.19 in
section (b) - 0.19 in

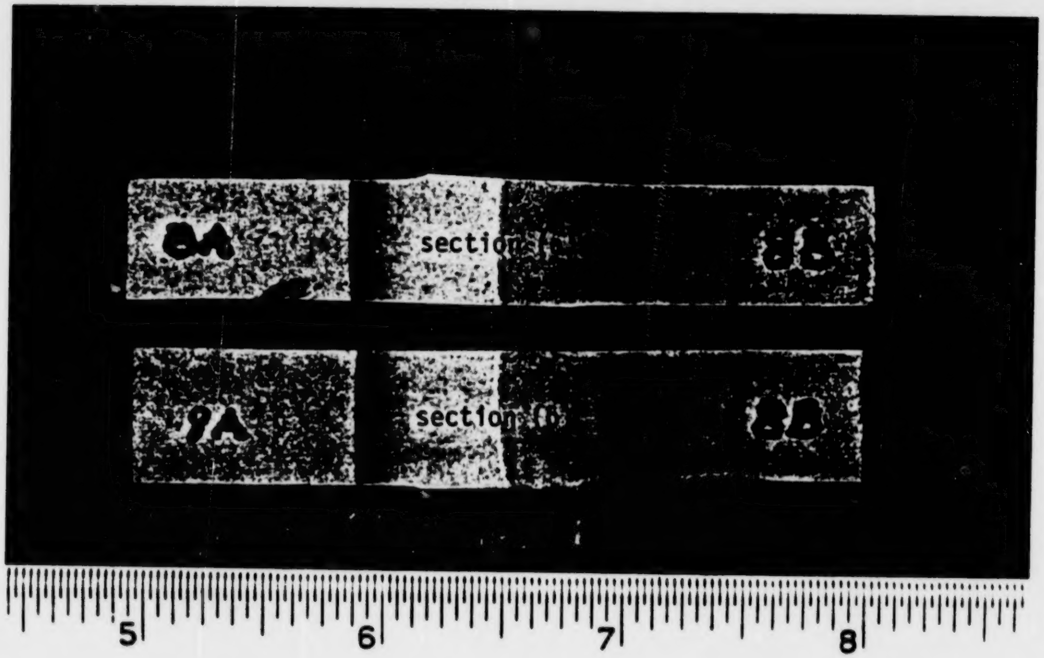
Figure 3: Heat-Affected-Zone Patterns, Weld No. 5, Sections (a) and (b)


6B
section (a)
6A
6B
section (b)
6A
5
6
7
8

maximum
width of HAZ

section (a) - 0.16 in
section (b) - 0.15 in

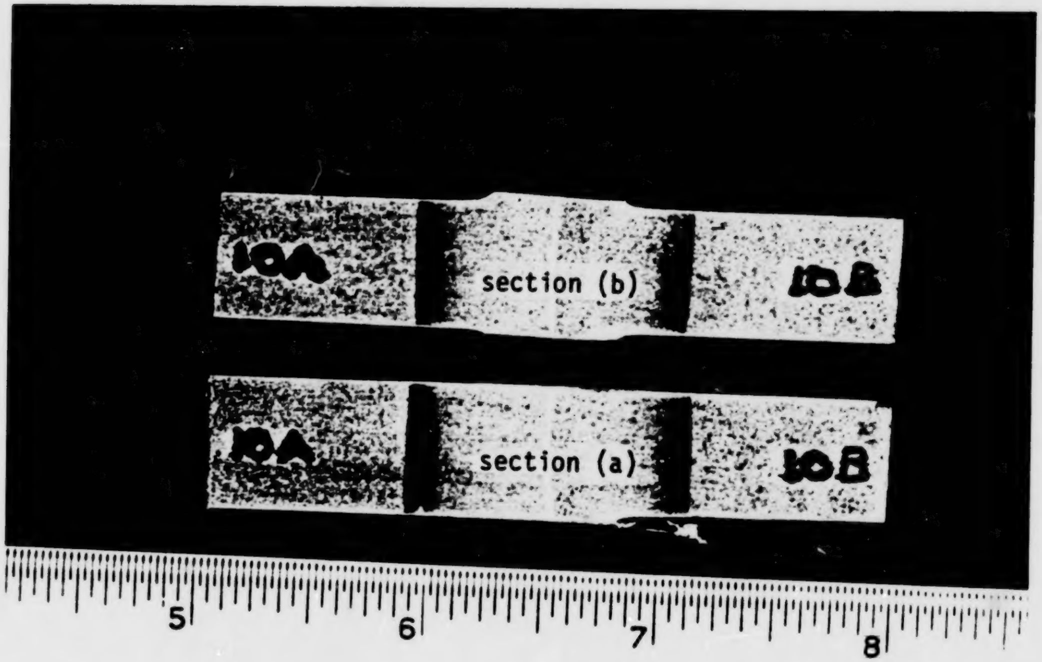
Figure 4: Heat-Affected-Zone Patterns, Weld No. 6, Sections (a) and (b)


8A
section
9A
section
5
6
7
8

maximum
width of HAZ

section (a) - 0.12 in
section (b) - 0.12 in

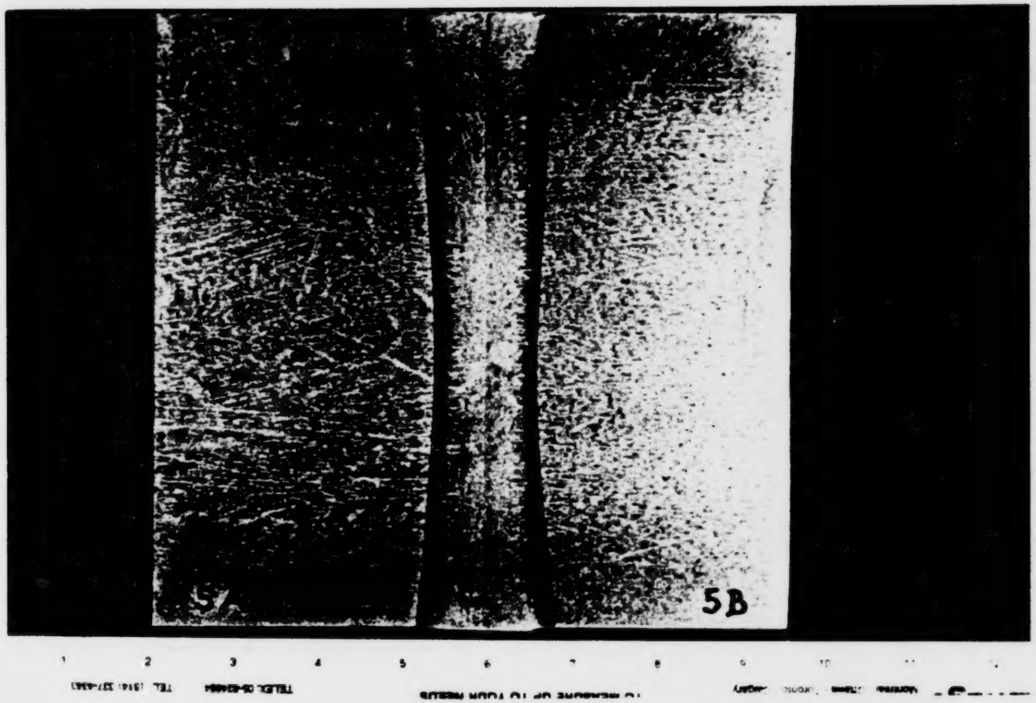
Figure 5: Heat-Affected-Zone Patterns, Weld No. 8, Sections (a) and (b)


10A
section (b)
10B
10A
section (a)
10B
5
6
7
8

maximum
width of HAZ

section (a) - 0.12 in
section (b) - 0.12 in

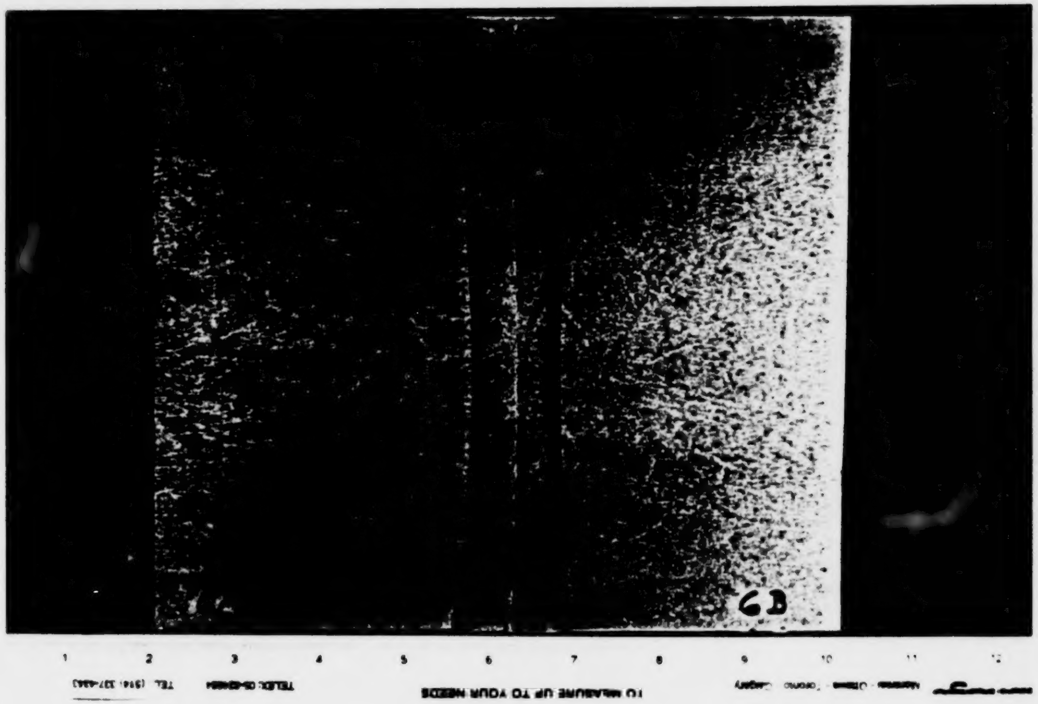
Figure 6: Heat-Affected-Zone Patterns, Weld No. 10, Sections (a) and (b)


5B
1
2
3
4
5
6
7
8
9
10
11
12

maximum
width of HAZ

head - 0.21 in
web - 0.14 in
base - 0.18 in

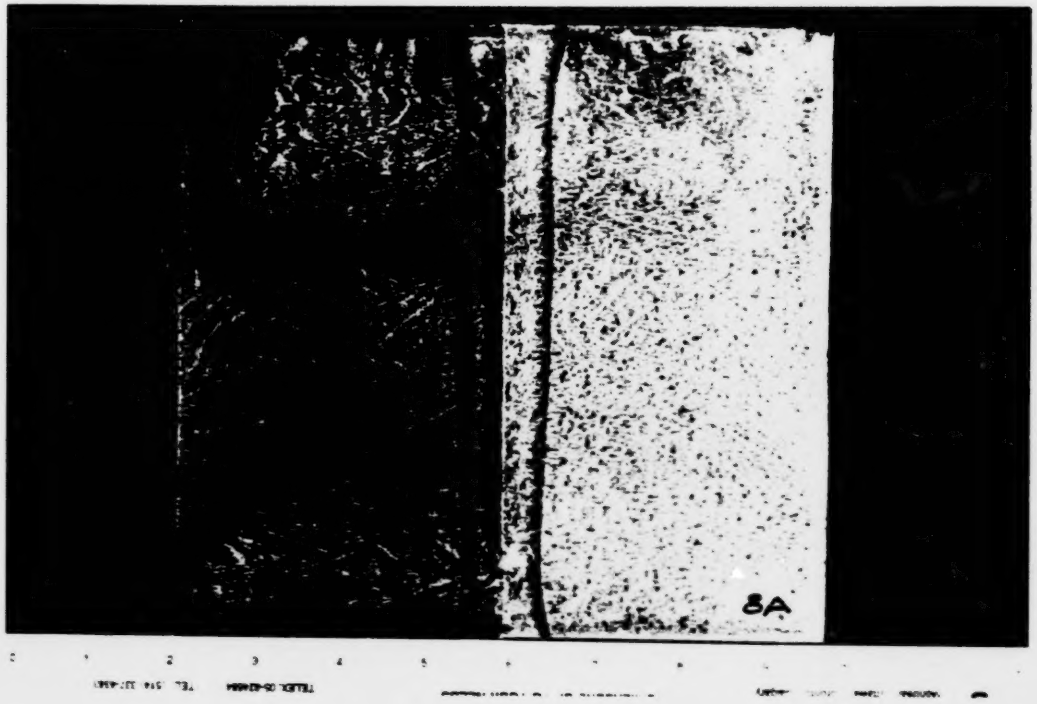
Figure 7: Heat-Affected-Zone Pattern, Weld No. 5, Section (c)


6B
1
2
3
4
5
6
7
8
9
10
11
12

maximum
width of HAZ

head - 0.17 in
web - 0.12 in
base - 0.14 in

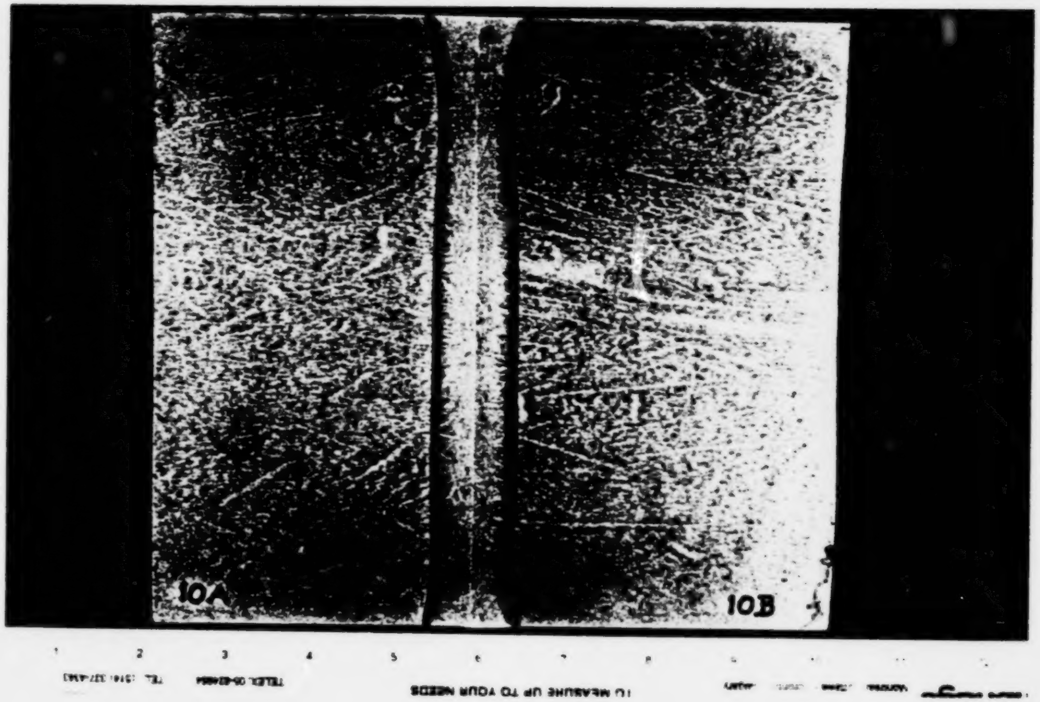
Figure 8: Heat-Affected-Zone Pattern, Weld No. 6, Section (c)



maximum
width of HAZ

head - 0.14 in
web - 0.11 in
base - 0.11 in

Figure 9: Heat-Affected-Zone Pattern, Weld No. 8, Section (c)


10A
10B
1
2
3
4
5
6
7
8

maximum
width of HAZ

head - 0.13 in
web - 0.11 in
base - 0.09 in

Figure 10: Heat-Affected-Zone Pattern, Weld No. 10, Section (c)

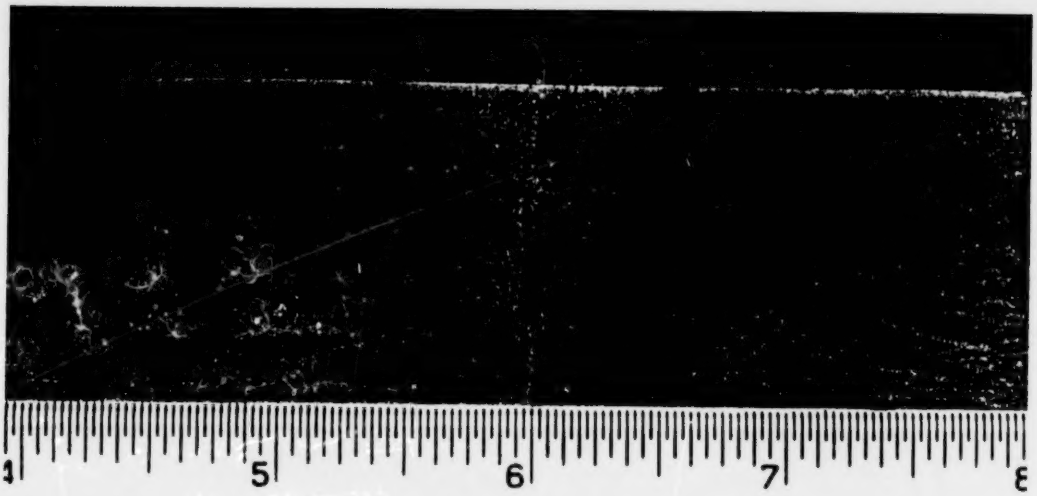


Figure 11: Dark Etch Area Observed on Weld Bond Line in Head of Weld No. 10

2.2 Hardness Surveys

2.2.1 Sections (a) and (b)

Figures 12-15 present graphically the results of Vickers microhardness traverses performed on sections (a) and (b) for each of welds 5, 6, 8 and 10, respectively. The tables of individual microhardness values (see Tables II.1-II.4) are listed in Appendix II.

The hardness values determined in the surveys of the (a) and (b) sections do not indicate any abnormal or unacceptable conditions (i.e. martensite). Hardness values are slightly higher here (eg. 20-30 BHN) than in corresponding (c) sections -- this is consistent with the faster cooling rates of the (a) and (b) sections.

All microhardness gradients are acceptable. In terms of the magnitude and consistency of hardness across the traverse, weld no. 10 exhibits the best microhardness pattern -- just slightly superior to that exhibited by weld no. 8. It is noted that hardness peaks exhibited by weld no. 10 did not reach, but were approaching, unacceptably high values (microhardness values of 475-500 VHN would suggest the presence of martensite). The cooling rates experienced by sections (a) and (b) of weld no. 10 closely approached those which would result in a structure containing bainite and/or martensite.

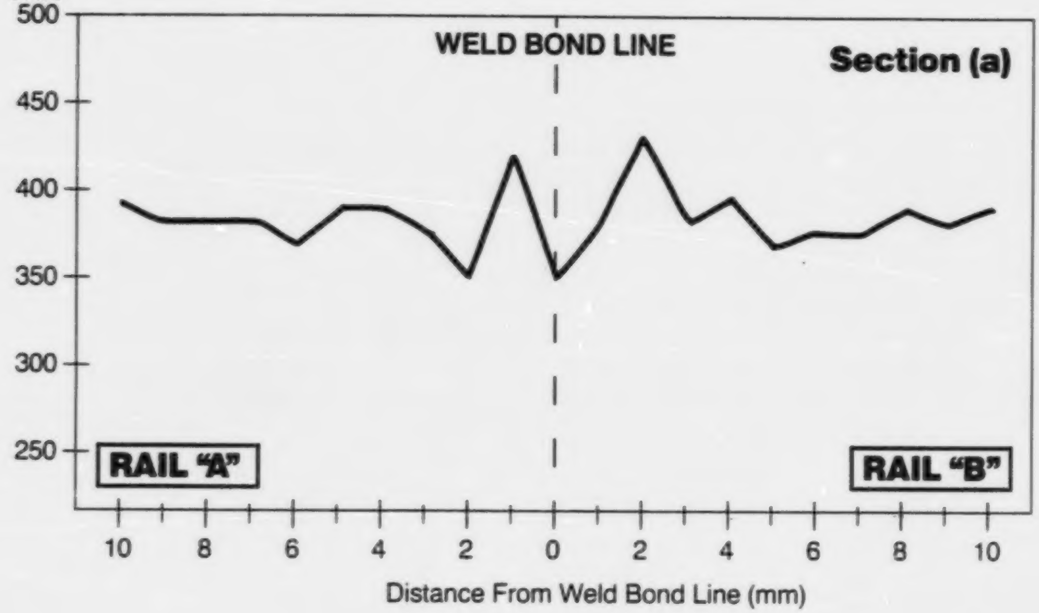
2.2.2 Section (c)

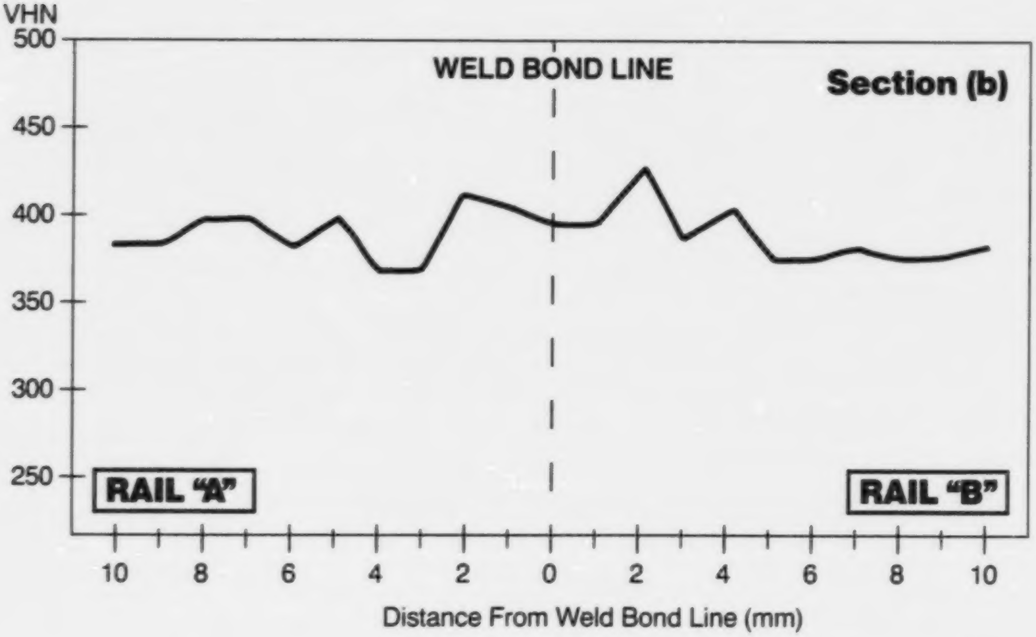
Figures 16-19 illustrate the results of Rockwell hardness traverses made on section (c) of welds 5, 6, 8 and 10, respectively. The tables of individual hardness values (see Tables III.1-III.4) are attached as Appendix III of this report.

The hardness values determined in the surveys do not indicate any abnormal responses, nor any excessively hard areas -- this applies to each of the head, web and base sections examined. As is expected for head-hardened rails, peak head-hardnesses in the weld HAZs are of the same order as the parent metal (PM). Hardness differences across the WBL largely result from different initial hardnesses of the mated rails.

For welds 5, 6 and 8, the typical drop in head-hardness at the PM/HAZ boundary was 10-12 Rc (approximately 100 BHN) -- this drop occurred over a range of 0.12-0.24 inches (3-6 mm). As well, WBLs for these welds exhibited slightly lower (5-7 Rc) head-hardness values than the surrounding HAZs. Weld no. 10 exhibits less distinct drops in hardness than the above welds (5-7 Rc and 1-2 Rc at the PM/HAZ and WBL boundaries, respectively). It is suggested that the observed drop in hardness at the PM/HAZ boundary is a characteristic of the welding machine used and does not reflect a major fundamental weakness in either the welding cycles studied or the AWC-340 rail itself. The drop in hardness at the WBL results from decarburized material that was not removed during weld upset, and is not abnormal.

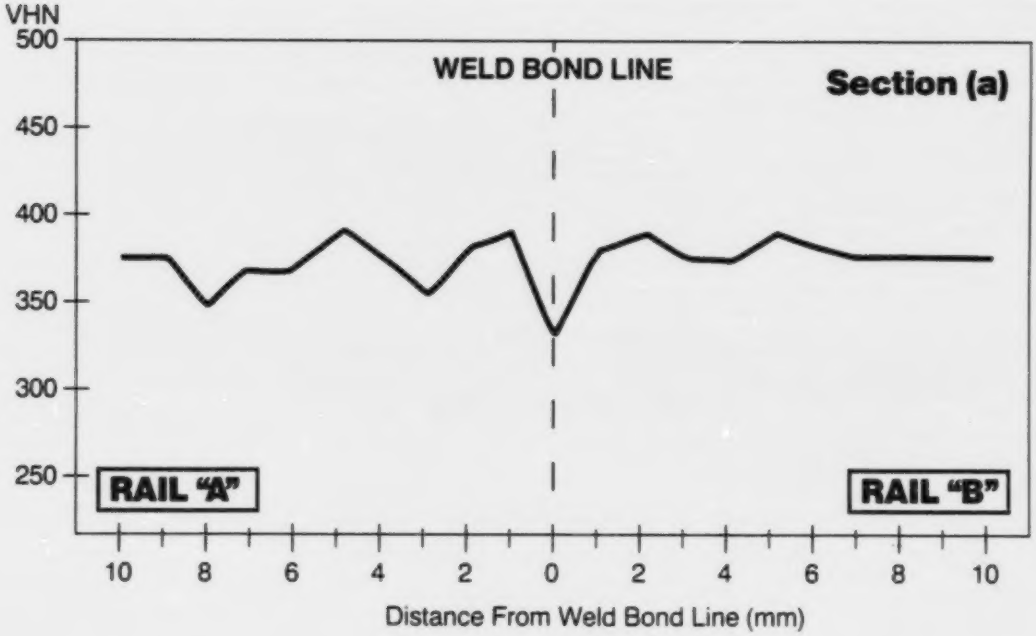
All hardness gradients are acceptable. Weld no. 10 exhibits the best hardness pattern, followed closely by that of weld no. 8.

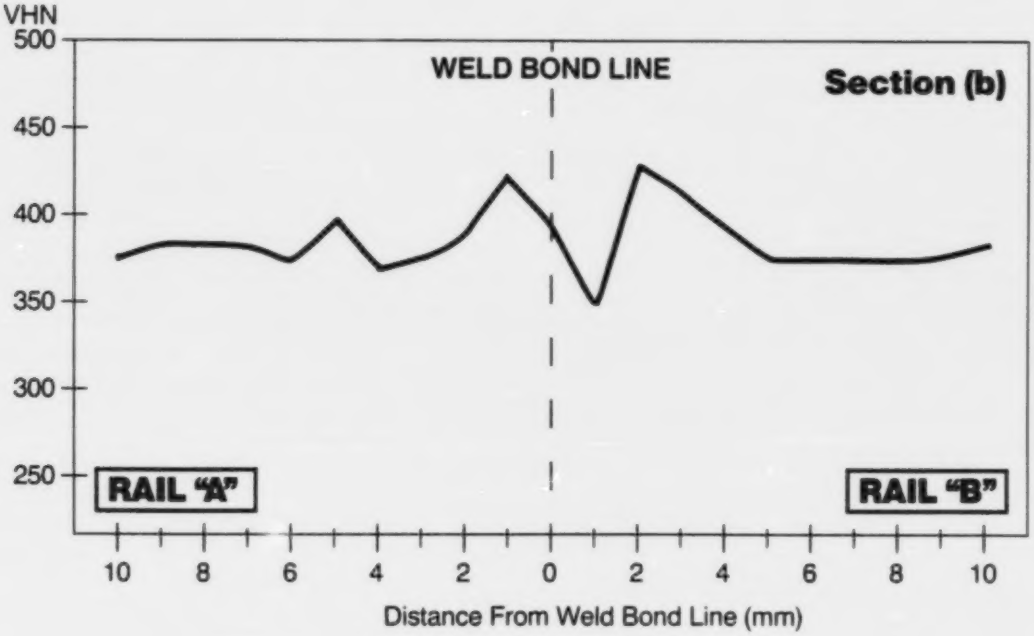




MICROHARDNESS SURVEY OF WELD No. 5
Section (a) and Section (b)

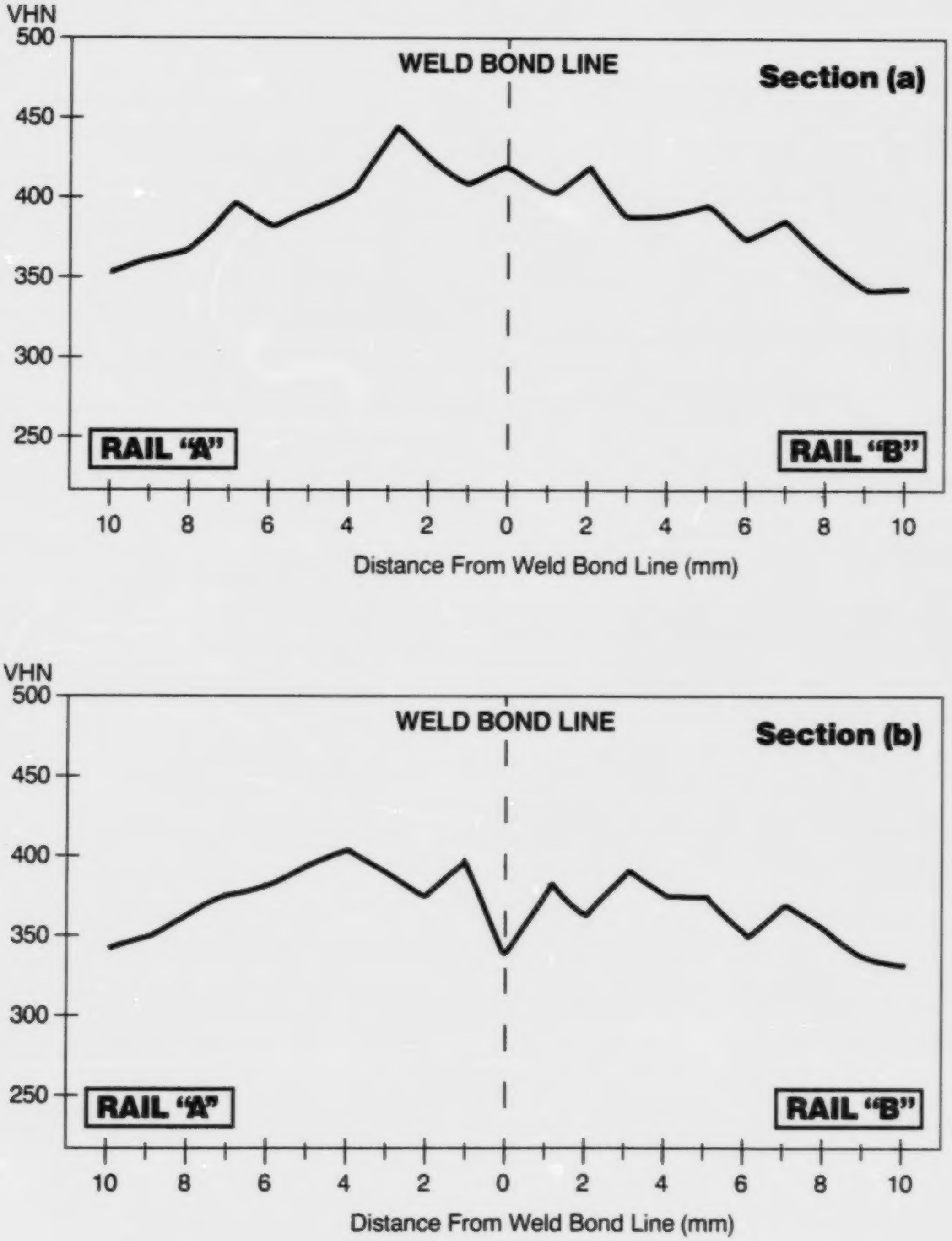
Figure 12





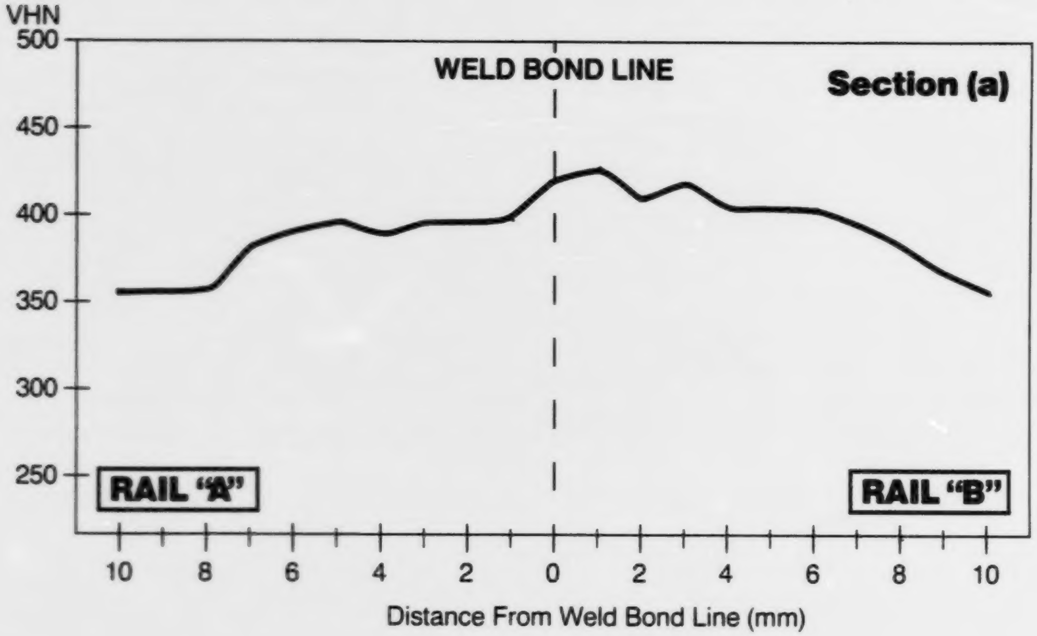
MICROHARDNESS SURVEY OF WELD No. 6
Section (a) and Section (b)

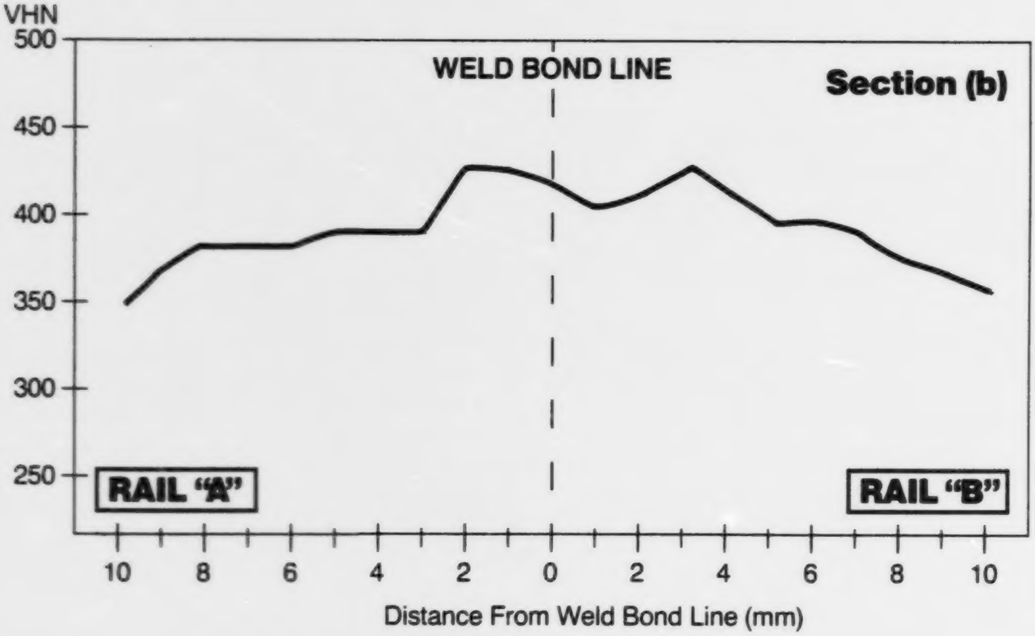
Figure 13



MICROHARDNESS SURVEY OF WELD No. 8
Section (a) and Section (b)

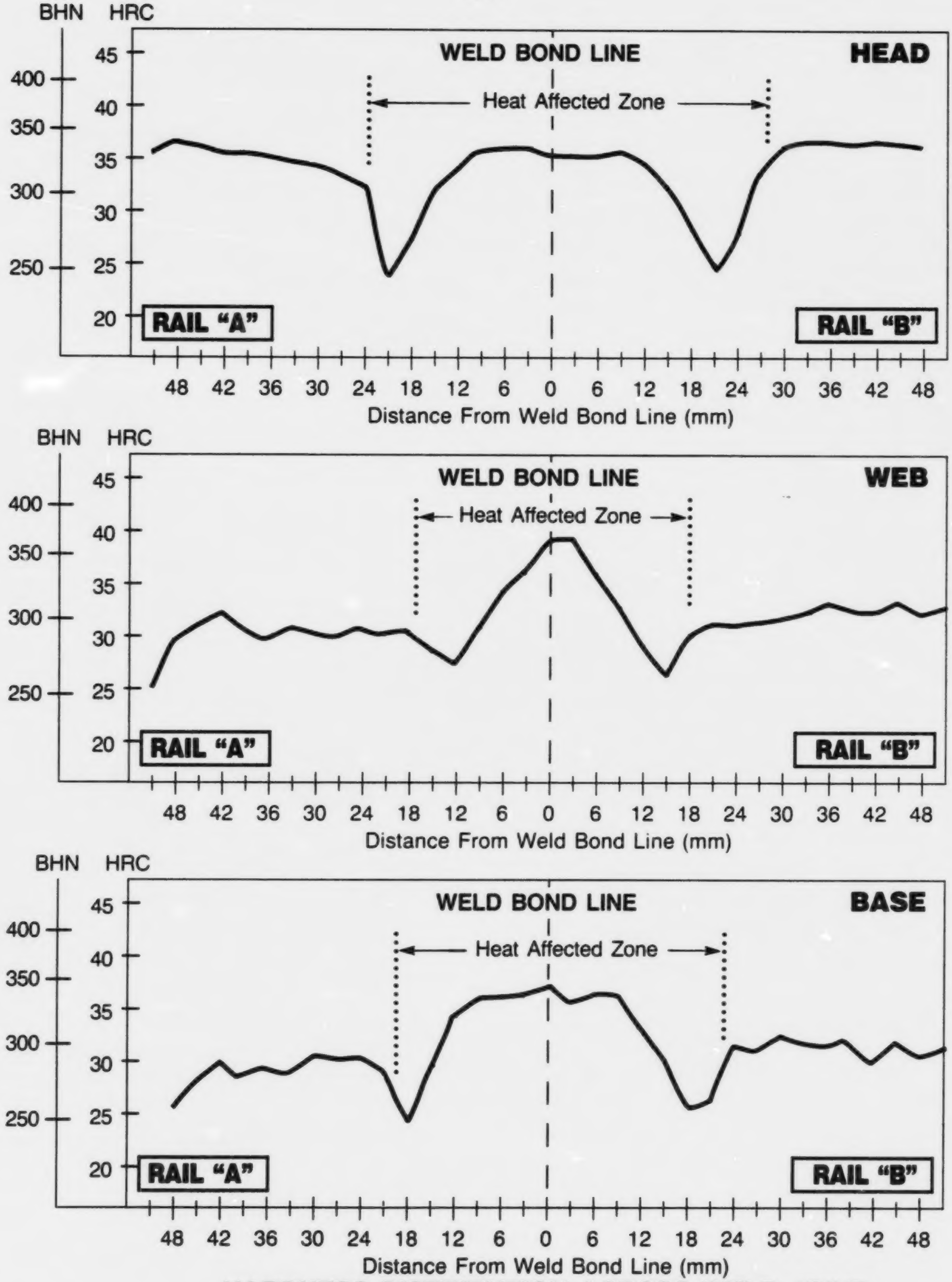
Figure 14





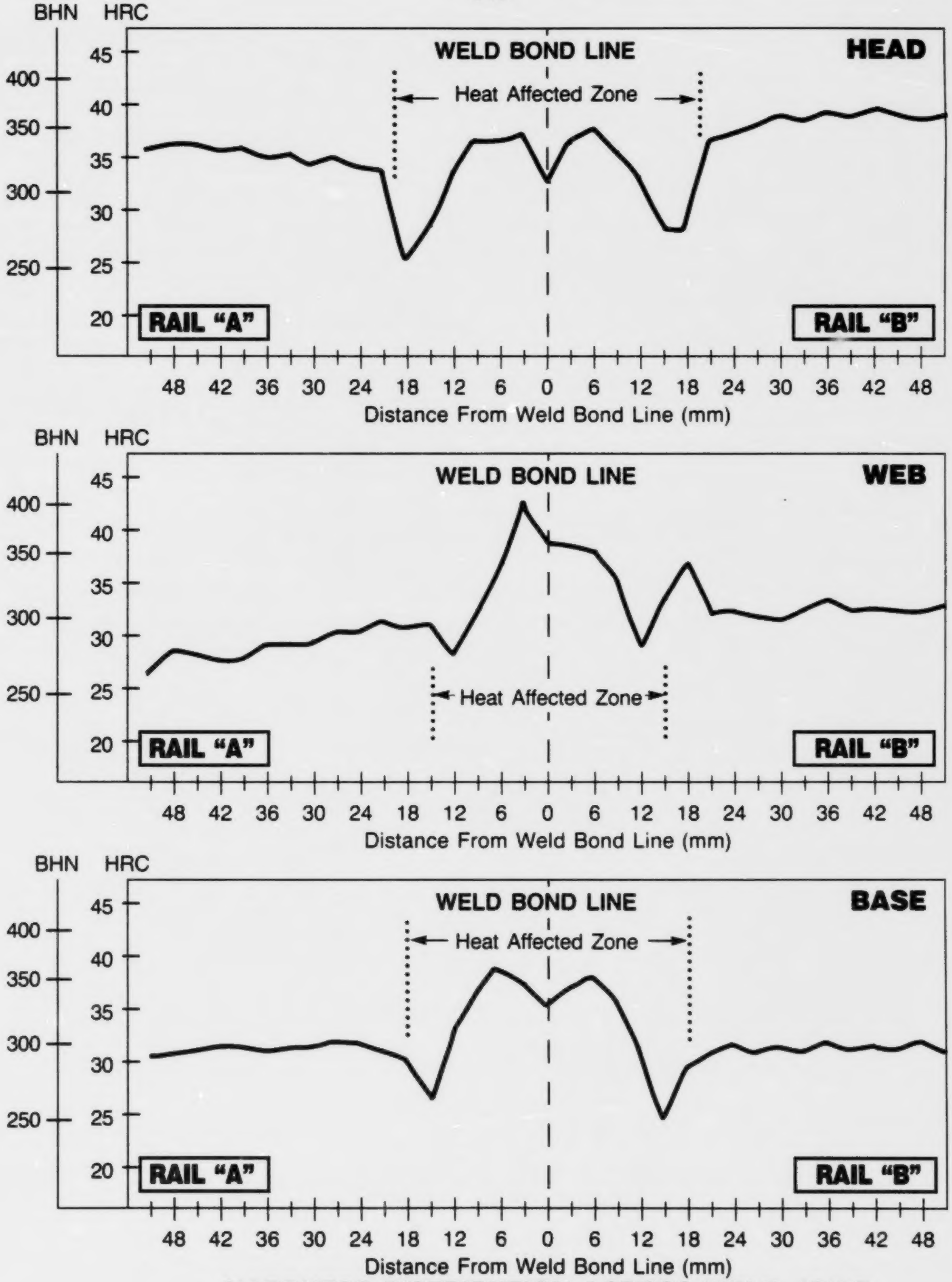
MICROHARDNESS SURVEY OF WELD No. 10
Section (a) and Section (b)

Figure 15



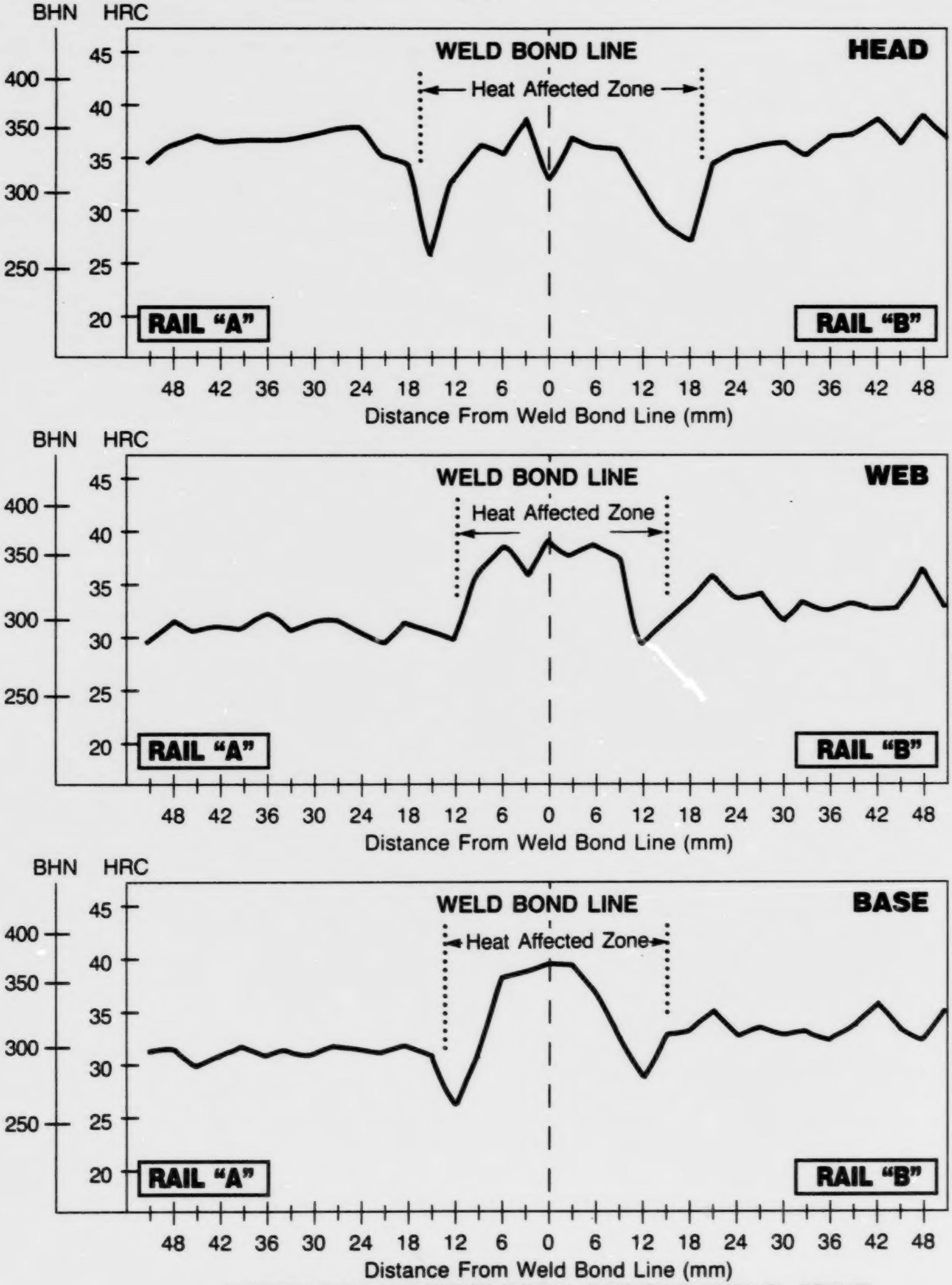
HARDNESS DISTRIBUTION ACROSS WELD JOINT OF AWC-340 RAIL (weld no. 5)

Figure 16



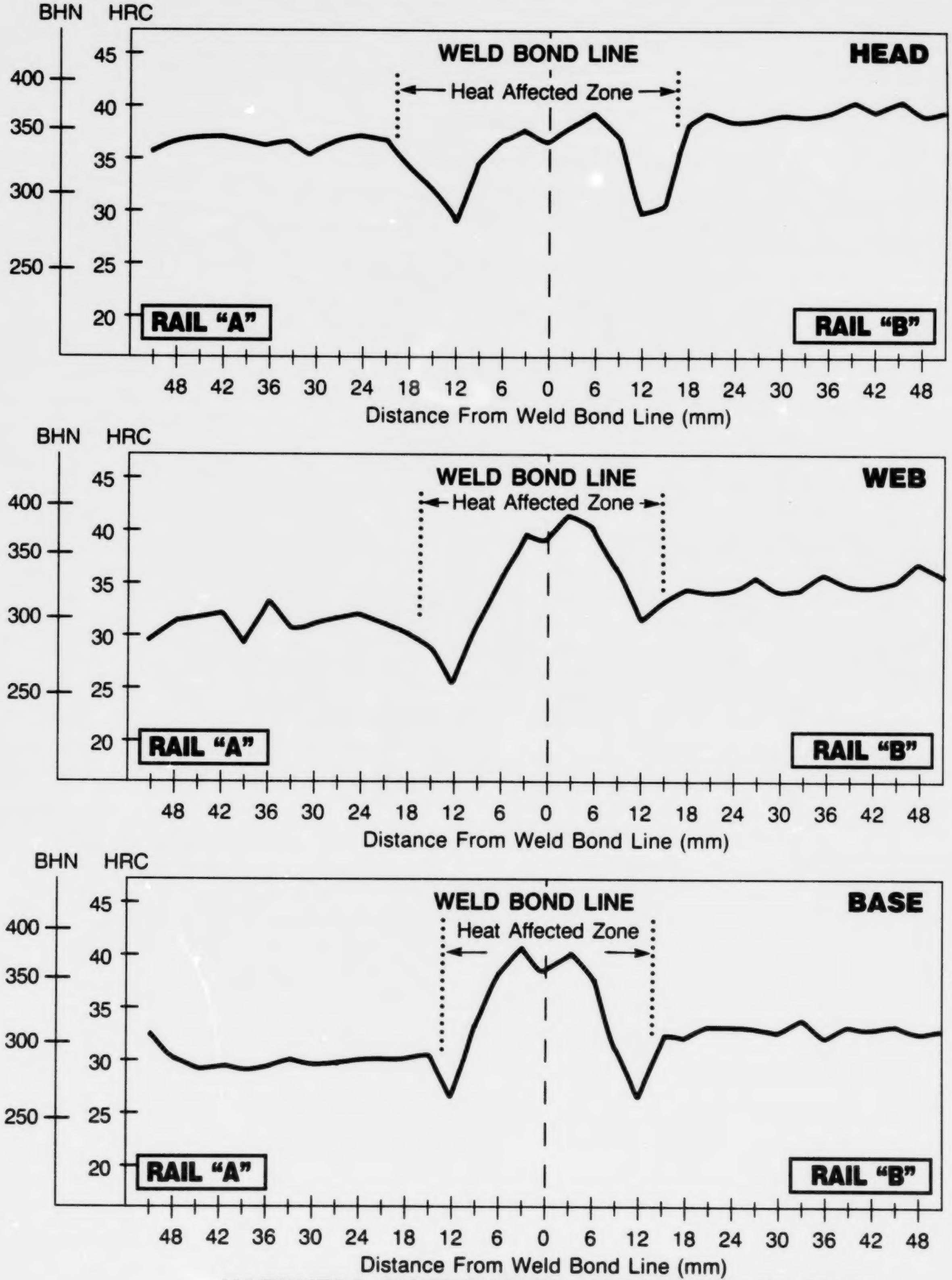
HARDNESS DISTRIBUTION ACROSS WELD JOINT OF AWC-340 RAIL (weld no. 6)

Figure 17



HARDNESS DISTRIBUTION ACROSS WELD JOINT OF AWC-340 RAIL (weld no. 8)

Figure 18



HARDNESS DISTRIBUTION ACROSS WELD JOINT OF AWC-340 RAIL (weld no. 10)

Figure 19

2.3 Microstructural Analysis

A large number of photomicrographs were taken, as prescribed by the CP Rail procedure -- Appendix I. While it is not feasible to include all of these in this report, representative samples are presented.

2.3.1 Sections (a) and (b)

Figure 20 is a typical photomicrograph of the pearlitic structure which characterizes all sections (a) and (b). There is no evidence of any significant formation of martensite in the structure of any of the weld sections (a) and (b) examined. This is consistent with the values obtained in the microhardness surveys previously reported in Section 2.2.1.

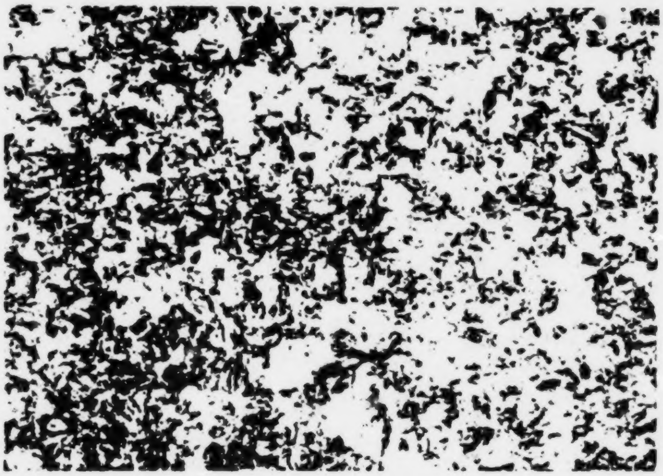


Figure 20: Weld No. 8, Section (a), Fusion Line (100X, 2% nital etch)

2.3.2 Section (c)

Figures 21-23 are representative photomicrographs of the general structures found in the head, web and base, respectively, of each of welds 5, 6, 8 and 10.

Welds 5, 6 and 8 all exhibit a wholly pearlitic structure, Weld no. 10 exhibits an essentially pearlitic structure, but has isolated "blocky" bainite patches on the WBL in the rail head (see Figure 24). As well, there is a gradual refinement in grain structure from welds 5 to 6 to 8 and 10, with little discernible difference between welds 8 and 10. This refinement in grain structure results from a gradual reduction in total heat input during the preheat stage of the flash butt welding process.

There is no evidence of any significant formation of martensite in the structure of any of the weld sections examined. The isolated bainite patches observed on the WBL in the head of weld no. 10 are not dangerous, but are undesirable. Further, a cooling rate just slightly faster than that experienced in the head of weld No. 10 would likely produce either greater amounts of bainite (undesirable) or even martensite (possibly dangerous); therefore, the weld cycle used to produce weld no. 10 should not be pursued. Weld no. 8 exhibits the most desirable microstructure of all the welds examined.

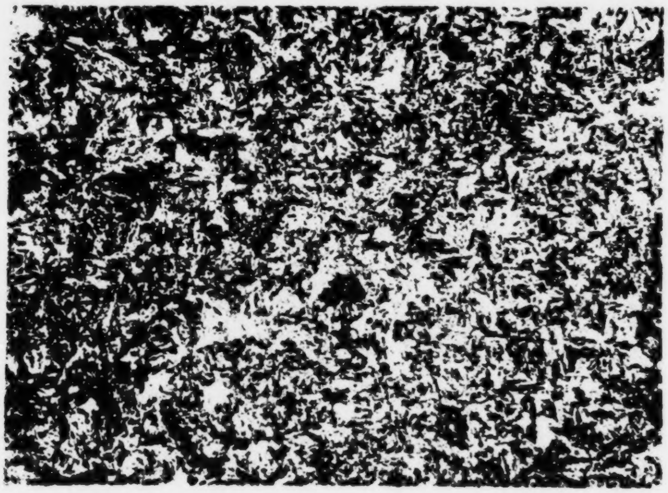


Figure 21: Rail Head, Weld No. 8, Fusion Line, Section (c)
(100X, 2% nital etch)

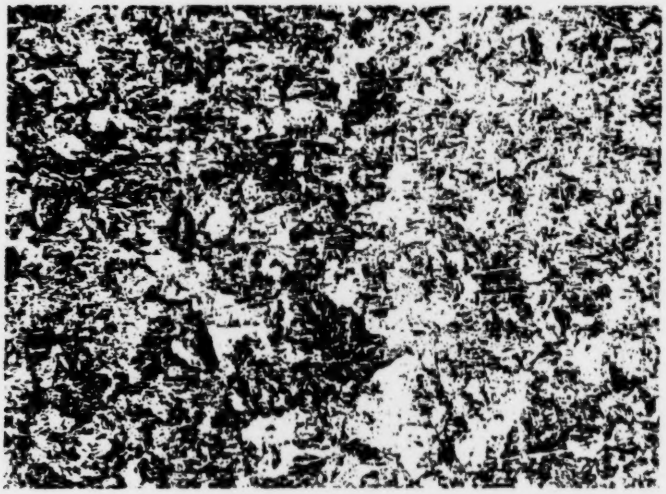


Figure 22: Rail Web, Weld No. 8, Fusion Line, Section (c) (100X, 2% nital etch)

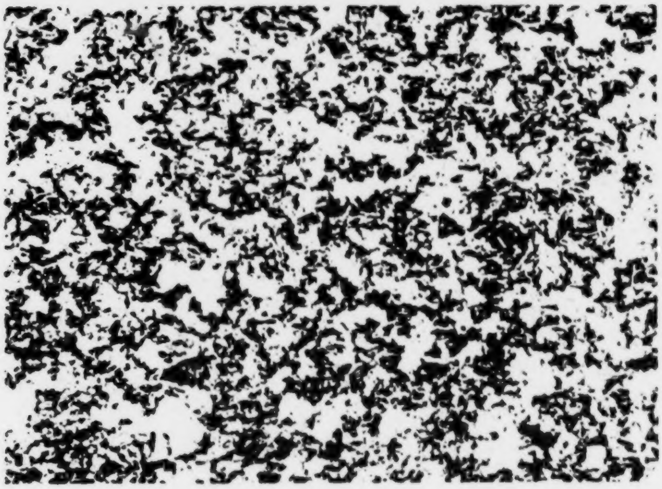


Figure 23: Rail Base, Weld No. 8, Fusion Line, Section (c) (100X, 2% nital etch)

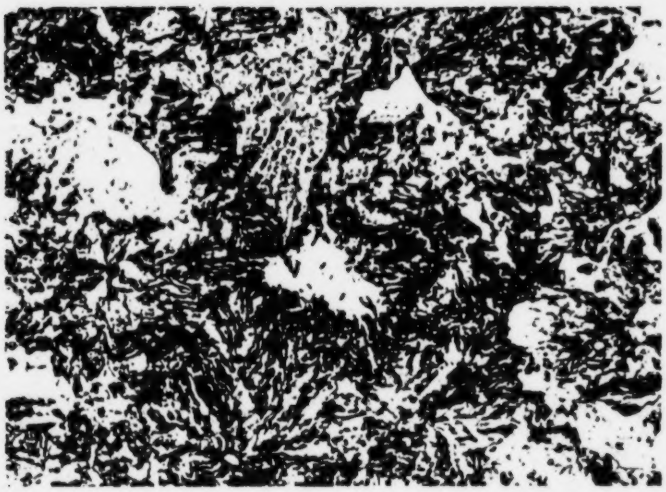


Figure 24: Bainitic Patch on Fusion Line in Head of Weld No. 10 (250X, 2% nital etch)

2.4 Fracture Test

Two further welds (no.'s 12 and 13, see Table 5) were made using the same preheat pattern as was employed for weld no. 8 (i.e. 7 preheats, 2.5 sec. power on, 5.0 sec. power off).

Table 5

Trial Welds Produced for Fracture Test

Weld No.	Rail No.'s Welded Together Rail A	 Rail B
12	1	2
13	1	2

A 58 inch section from each of welds 12 and 13 was then prepared and loaded in three-point bending. These welds each fractured between 230-235 tons -- an acceptable level. Further, their fracture surfaces were clean with no inclusions nor any indications of burnt metal or incomplete fusion. Eight inch sections of welds 12 and 13 were sent to Algoma Steel for dissection and metallurgical analysis. The results of this investigation will be available in a future report, along with those of welds 7, 9 and 11.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Weld no. 8 is the best weld of those examined in terms of the width of its HAZ, the hardness contours and transformation products exhibited across its weld zone, and its general internal quality. Weld no. 8 is of an acceptable metallurgical quality.

The weld cycle (preheat stage: 7 preheats, 2.5 sec. power on, 5.0 sec. power off) used to produce weld no. 8 should be employed in the welding of AWC-340 rail sections submitted to CP Rail by Algoma Steel for field testing.

APPENDIX I

PROCEDURE FOR THE METALLURGICAL EVALUATION OF FLASH BUTT WELDED RAILS

Each welded rail sample will be sectioned as shown in Figure I.1 for metallography and hardness measurements. The two smaller pieces, sections (a) and (b), taken from the foot of the base will be used for micrography and Vickers microhardness measurements. Section (c), which contains the head, web and base of the welded rails, will be used for macrography and Rockwell (Rc) hardness traverses. Section (c) will be subsequently dissected and its various microstructures examined.

Since the rail base flanges cool very rapidly, and are prone to martensite formation, the outer 0.25 in (6.35mm) of sections (a) and (b) will be removed from all samples prior to examination. The remaining outer surfaces (see Figure I.1) will then be ground, polished and etched in 2% nital. Photomicrographs of these surfaces are to be taken 0.08-0.16 in (2-4mm) from the weld bond line (see Figure I.2) at magnifications of 50X and 100X. A standard point counting technique will be performed on these photomicrographs to determine the proportion of untempered martensite, along with other structures, present in the weld heat-affected-zone. Vickers microhardness measurements (VHN) are to be taken on the etched surfaces of sections (a) and (b) at 0.88 lbs (400g) load. These measurements will begin 0.25 in (6.35mm) up from the base of sections (a) and (b); indentations will be made on the weld bond line and on both sides of this line -- at 0.04 in (1mm) intervals -- up to 0.40 in (10mm) from the weld bond line (see Figure I.3). The primary aim of examining sections (a) and (b) is to determine/reveal whether significant non-uniformity in heat distribution existed between the front and rear of the rails throughout the welding cycle.

The interior surface of section (c) is to be ground and polished prior to macroetching. This surface will be washed with alcohol and dried, and then etched in a hot (60°c) hydrochloric acid:water solution (50:50) for 10 minutes. Section (c) is to then be washed with water and alcohol, and dried after etching. This etched surface is to be photographed and examined for defects (eg. - voids, incomplete bonds and cracks) at and/or around the weld bond line. The maximum width of the weld heat-affected-zone is to be measured in the head, web and base. At this time the etched surfaces of sections (a) and (b) should be re-ground and prepared in the same manner as used for section (c) above. A study of the macroetched surfaces of sections (a), (b) and (c) together will more fully reveal any significant non-uniform heating pattern which may have occurred during the weld cycle.

Rockwell (Rc) hardness traverses are to be made on and across the weld bond line on the macroetched surface of section (c) at three different levels in the rail (see Figure I.4). The indentations are to be made within the head (0.25 in/6.35mm below the railhead surface), mid-web (3.44 in/87.31mm below the railhead surface) and mid-base (0.25 in/6.35mm up from the bottom surface of the rail). These measurements are to be made at 0.12 in (3mm) intervals, and should extend up to 2 in (50mm) away from both sides of the weld bond line. Microstructural samples are to be removed from section (c) at each of the three depths investigated, from points 0.08-0.16 in (2-4mm) on both sides of the weld bond line. These samples are to be re-ground, polished and etched in 2% nital. Photomicrographs of these samples are to be taken at 100X. Examination of section (c) in the above manner can reveal the relative influence of different welding parameters/practices on the width of the heat-affected-zone, final microstructure, proportions of untempered martensite and other metallurgical resultants which together determine the quality of the weld.

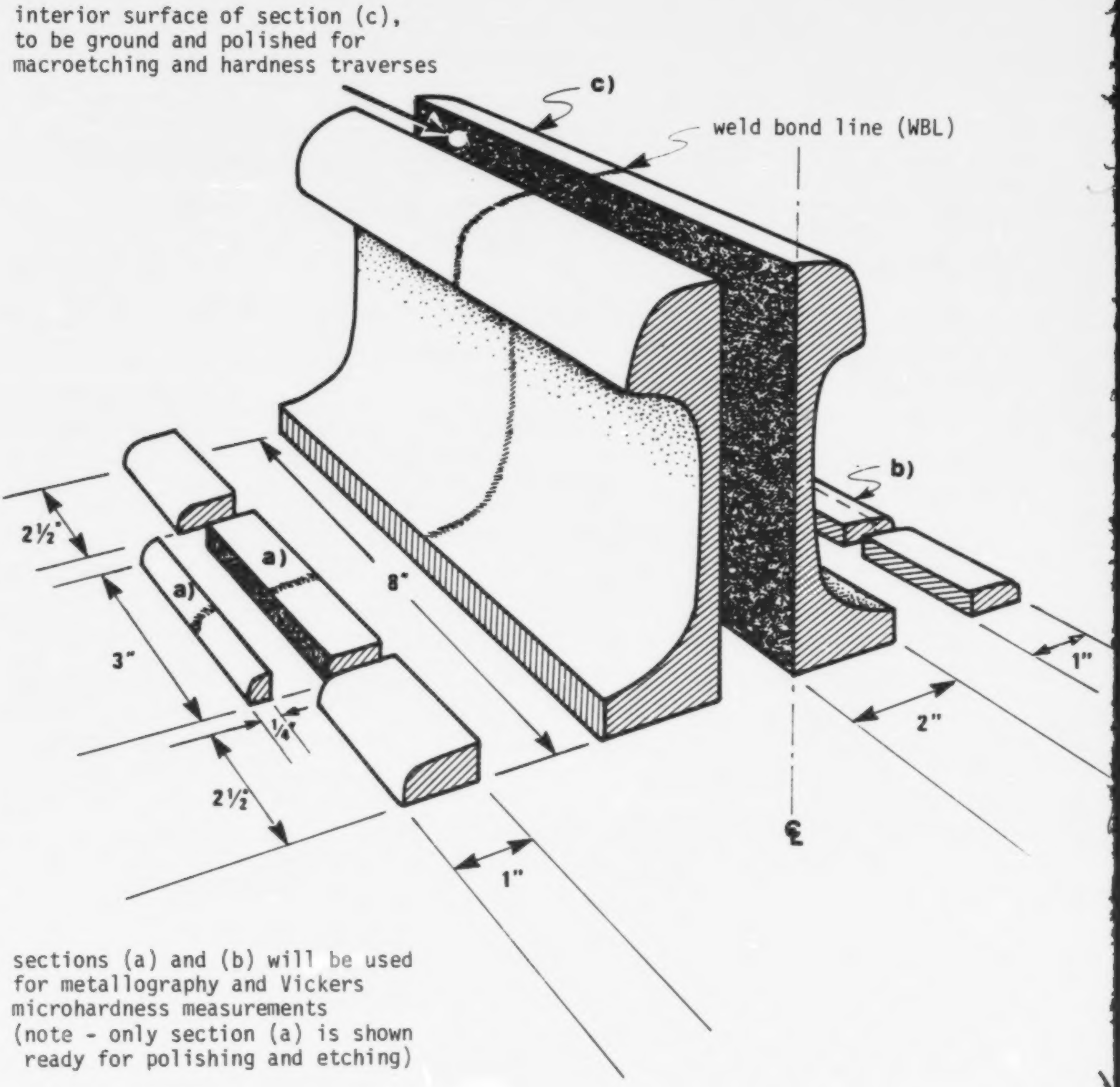

interior surface of section (c), to be ground and polished for macroetching and hardness traverses
c)
weld bond line (WBL)
b)
a)
a)
2½"
3"
¼"
2½"
8"
1"
1"
2"
℄
sections (a) and (b) will be used for metallography and Vickers microhardness measurements
(note - only section (a) is shown ready for polishing and etching)

Figure I.1: Schematic of Required Sectioning of Welded Rail Samples for Metallography and Hardness Measurements

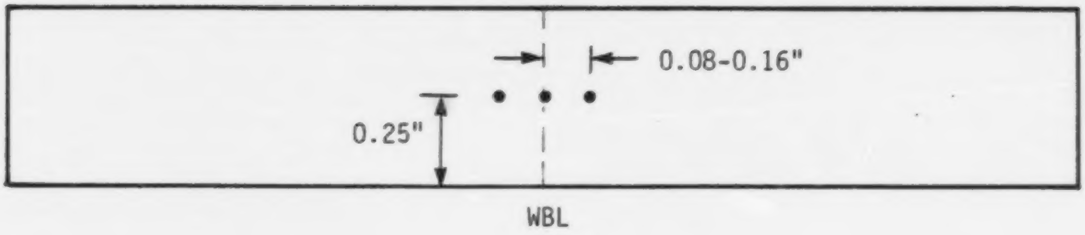


Figure I.2: Locations on Etched Surfaces of Sections (a) and (b) where Photomicrographs are to be Taken at 50x and 100x (not to scale)

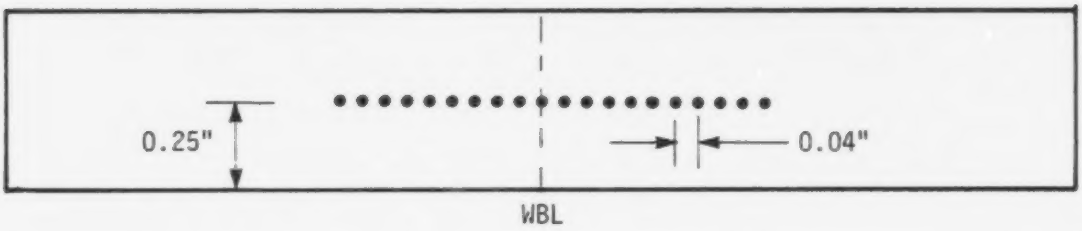


Figure I.3: Locations on Etched Surfaces of Sections (a) and (b) where Vickers Microhardness Measurements are to be Taken (not to scale)

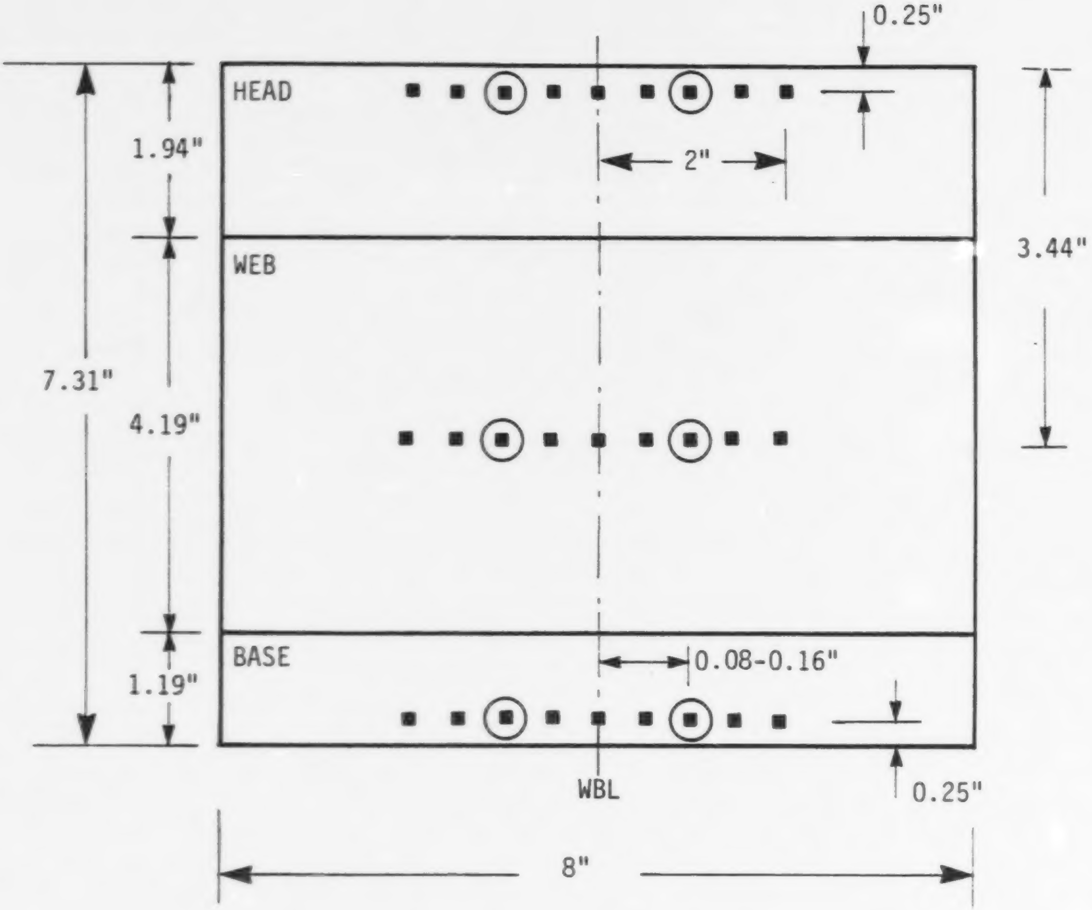

0.25"
HEAD
1.94"
2"
WEB
3.44"
7.31"
4.19"
BASE
0.08-0.16"
1.19"
WBL
0.25"
8"

Figure I.4: Locations on Macroetched Surface of Section (c) where Rockwell (Rc) Hardness Traverses are to be Performed (not to scale, circles designate locations for subsequent removal of microstructural samples)

APPENDIX II

Vickers Microhardness Surveys of Sections (a) & (b)

Measurement locations are spaced every 1 mm (0.04 in) from the fusion line, in compliance with the standard procedure used by CP Rail in the evaluation of flash butt rail welds (see Appendix I).

load = 2.5 kg 136° diamond pyramid indentor

Table II. 1: Microhardness Survey Across Weld No. 5

Location		VHN Section (a)	VHN Section (b)
Rail A			
	10	390	383
	9	383	383
	8	383	397
	7	383	397
	6	369	383
	5	390	397
	4	390	369
	3	376	369
	2	350	412
	1	420	405
	Fusion Line	350	397
	1	383	397
	2	428	428
	3	383	376
	4	397	405
	5	369	376
	6	376	376
	7	376	383
	8	390	376
	9	383	376
	10	390	383
Rail B			

Table II. 2: Microhardness Survey Across Weld No. 6

	VHN	
Location	Section (a)	Section (b)
Rail A		
10	376	376
9	376	383
8	350	383
7	369	383
6	369	376
5	390	397
4	376	369
3	356	376
2	383	390
1	390	420
Fusion Line	333	397
1	383	350
2	390	428
3	376	412
4	376	390
5	390	376
6	383	376
7	376	376
8	376	376
9	376	376
10	376	383
Rail B		

Table II. 3: Microhardness Survey Across Weld No. 8

	VHN	
Location	Section (a)	Section (b)
Rail A		
10	356	344
9	363	350
8	369	363
7	397	376
6	383	383
5	397	397
4	405	405
3	445	390
2	420	376
1	412	397
Fusion Line	420	338
1	405	383
2	420	363
3	390	390
4	390	376
5	397	376
6	376	350
7	383	369
8	363	356
9	344	338
10	344	333
Rail B		

Table II. 4: Microhardness Survey Across Weld No. 10

	VHN	
Location	Section (a)	Section (b)
Rail A		
10	356	350
9	356	369
8	356	383
7	383	383
6	390	383
5	397	390
4	390	390
3	397	390
2	397	428
1	397	428
Fusion Line	420	420
1	428	405
2	412	412
3	420	428
4	405	412
5	405	397
6	405	397
7	397	390
8	383	376
9	369	369
10	356	356
Rail B		

APPENDIX III

Hardness Surveys of Section "c"

Measurement locations are spaced every 3 mm (0.12 in) from the fusion line, in compliance with the standard procedure used by CP Rail in the evaluation of flash butt rail welds (see Appendix I).

Measurements were performed with a LECO RT-120 hardness tester (calibrated to ± 0.5 Rc) -- hardness values were subsequently converted to the BHN scale for ease of study.

Table III. 1: Hardness Survey Across Weld No. 5

		Head		Web		Base	
	Location	HRC	BHN	HRC	BHN	HRC	BHN
Rail A							
	17	35.7	333	25.3	255	16.4	---
	16	36.7	342	29.6	283	25.6	256
	15	36.1	337	31.1	295	28.5	275
	14	35.5	332	32.3	304	30.0	286
	13	35.5	332	30.4	289	28.9	278
	12	35.1	328	30.0	286	29.4	282
	11	34.7	325	30.9	293	29.0	279
	10	34.3	321	30.2	288	30.7	292
	9	33.2	313	30.0	286	30.2	288
	8	32.5	306	30.7	292	30.4	289
	7	23.7	246	30.1	287	28.9	278
	6	27.0	264	30.2	288	24.0	247
	5	32.4	305	28.5	275	29.7	284
	4	34.0	319	27.4	267	34.3	321
	3	35.7	333	31.0	294	36.1	337
	2	36.0	336	34.3	321	36.1	337
	1	36.0	336	36.0	336	36.3	338
	Fusion Line	35.3	330	39.1	363	37.3	347
	1	35.3	330	39.1	363	35.8	334
	2	35.2	329	36.0	336	36.5	340
	3	35.6	332	32.9	310	36.1	337
	4	34.6	324	29.2	280	33.2	313
	5	32.5	306	26.1	259	30.2	288
	6	28.3	273	30.1	287	25.4	255
	7	24.3	249	31.2	295	26.2	259
	8	27.8	270	31.1	295	31.6	298
	9	33.7	316	31.3	296	31.4	297
	10	36.3	338	31.8	300	32.5	306
	11	36.8	342	32.5	306	31.8	300
	12	36.8	342	33.3	313	31.6	298
	13	36.5	340	32.5	306	31.8	300
	14	36.9	343	32.5	306	29.9	285
	15	36.5	340	33.1	312	31.9	300
	16	36.2	338	32.2	303	30.5	290
	17	27.3	266	32.9	310	31.3	296
Rail B							

Table III. 2: Hardness Survey Across Weld No. 6

		Head		Web		Base	
	Location	HRC	BHN	HRC	BHN	HRC	BHN
Rail A							
	17	35.9	335	26.8	263	30.5	290
	16	36.2	338	28.8	277	30.8	292
	15	36.0	336	28.3	273	31.4	297
	14	35.8	334	27.7	269	31.5	298
	13	36.0	336	27.9	270	31.4	297
	12	35.1	328	29.1	280	31.0	294
	11	35.2	329	29.3	281	31.5	298
	10	34.6	324	29.5	283	31.5	298
	9	35.0	327	30.3	288	31.9	300
	8	34.4	322	30.4	289	31.9	300
	7	33.8	317	31.3	296	31.0	294
	6	25.1	254	30.7	292	30.1	287
	5	28.5	276	30.8	292	26.4	260
	4	33.9	318	27.1	265	32.8	309
	3	36.7	342	32.5	306	36.7	342
	2	36.8	342	36.8	342	38.3	356
	1	37.4	348	42.5	395	37.5	349
	Fusion Line	32.8	309	38.9	361	35.3	330
	1	36.1	337	38.6	358	37.3	347
	2	37.7	350	38.0	353	37.8	351
	3	35.6	332	35.2	329	35.6	332
	4	33.1	312	28.8	277	31.2	295
	5	28.3	273	33.6	316	24.9	252
	6	28.2	273	36.5	340	29.7	284
	7	36.9	343	32.3	304	31.0	294
	8	37.5	349	32.5	306	31.6	298
	9	38.0	353	31.9	300	30.8	292
	10	39.0	362	31.3	296	31.4	297
	11	38.5	358	32.3	304	31.2	295
	12	39.4	366	33.3	313	31.7	299
	13	39.0	362	32.5	306	31.3	296
	14	39.7	368	32.7	308	31.5	298
	15	39.0	362	32.4	305	31.3	296
	16	38.7	359	32.3	304	31.8	300
	17	38.8	360	32.7	308	31.2	295
Rail B							

Table III. 3: Hardness Survey Across Weld No. 8

		Head		Web		Base	
	Location	HRC	BHN	HRC	BHN	HRC	BHN
Rail A							
	17	34.7	325	29.8	285	31.3	296
	16	36.3	338	31.6	298	31.3	296
	15	37.1	345	30.6	291	30.0	286
	14	36.9	343	31.0	294	30.6	291
	13	36.9	343	31.0	294	31.5	298
	12	36.9	343	32.2	303	30.9	293
	11	37.0	344	30.8	292	31.1	295
	10	37.4	348	31.5	298	31.0	294
	9	37.6	350	31.7	299	31.6	298
	8	37.5	349	30.4	289	31.5	298
	7	35.2	329	29.9	285	31.2	295
	6	34.1	320	31.2	295	31.6	298
	5	25.8	257	30.5	290	30.7	292
	4	32.8	309	30.0	286	26.2	259
	3	36.2	338	36.3	338	30.7	292
	2	35.2	329	38.5	358	38.1	354
	1	38.5	358	36.1	337	38.7	359
	Fusion Line	32.8	309	39.2	364	39.3	365
	1	37.0	344	37.9	352	39.1	363
	2	36.0	336	38.8	360	36.6	341
	3	35.6	332	37.3	347	32.5	306
	4	31.9	335	29.2	281	28.7	297
	5	28.3	273	31.5	298	32.7	308
	6	27.2	265	33.5	315	33.0	311
	7	34.6	324	35.6	332	35.0	327
	8	35.7	333	33.8	317	32.6	307
	9	36.4	339	34.0	319	33.4	314
	10	36.5	340	31.5	298	32.8	309
	11	35.7	333	33.3	313	33.0	311
	12	37.3	347	32.7	308	32.6	307
	13	37.1	345	33.3	313	33.8	317
	14	38.8	360	32.8	309	35.5	332
	15	36.2	338	32.8	309	33.3	313
	16	39.2	364	36.6	341	32.4	305
	17	37.1	345	33.0	311	35.0	327
Rail B							

Table III. 4: Hardness Survey Across Weld No. 10

		Head		Web		Base	
	Location	HRC	BHN	HRC	BHN	HRC	BHN
Rail A							
	17	36.0	336	29.6	283	32.1	302
	16	36.7	342	31.4	297	30.0	286
	15	37.0	344	31.9	300	29.3	281
	14	37.2	346	32.2	303	29.4	282
	13	36.6	341	29.4	282	29.2	280
	12	36.4	339	33.2	313	29.4	282
	11	36.6	341	30.8	292	30.1	287
	10	35.8	334	31.2	295	29.9	285
	9	36.8	342	31.8	300	29.6	283
	8	37.2	346	32.1	302	30.0	286
	7	36.9	343	31.2	295	30.1	287
	6	34.4	322	30.2	288	30.1	287
	5	32.2	303	28.8	277	30.5	290
	4	28.9	278	25.8	257	26.4	260
	3	34.5	323	31.5	298	33.2	313
	2	36.8	342	35.7	333	38.3	356
	1	37.8	351	39.9	370	40.8	379
	Fusion Line	36.9	343	39.4	366	38.2	355
	1	38.4	357	41.4	385	40.1	372
	2	39.4	366	40.0	371	37.6	350
	3	36.6	341	36.5	340	31.1	295
	4	29.8	285	31.4	297	26.2	260
	5	30.7	292	33.3	313	32.4	305
	6	38.1	354	34.3	321	32.3	304
	7	39.1	363	34.1	320	33.2	313
	8	38.6	358	34.4	322	33.4	314
	9	38.8	360	35.2	329	32.7	302
	10	39.2	364	34.2	321	32.6	307
	11	39.2	364	34.8	325	33.9	318
	12	39.4	366	35.6	332	32.2	303
	13	40.5	376	34.9	326	33.3	313
	14	39.5	367	34.7	325	33.1	312
	15	40.2	373	35.1	328	33.2	313
	16	39.2	364	36.9	343	32.9	310
	17	39.3	365	35.7	333	33.0	311
Rail B							

RAIL EVALUATION -- OTHER PROGRAMS

In addition to that work discussed in the previous three reports, other work carried out under the Rail Evaluation program during the period April 1985 to March 1986 included:

NKK-AHH RAIL

Test strings of a low alloy, head-hardened, rail produced by Nippon Kokan K.K. of Japan were installed, along with standard NSC Superrail, at four different test sites on the Mountain Subdivision for in-service comparative wear testing in July 1985. The initial series of profile measurements on this rail, referred to as NKK-AHH rail, were performed immediately following their installation. Subsequent profile measurements were made in October 1985.

NSC SUPERRAIL & RUSSIAN P-65 RAIL -- UPDATE

Additional profile measurements were performed in July 1985 on the NSC Superrail (cumulative tonnage: 138.0 MGT) and Russian P-65 rail (cumulative tonnage: 197.6 MGT) situated at MPs 102.1 and 87.7, respectively, on the Thompson Subdivision. These measurements were performed to confirm the long-term stability of their previously determined wear patterns. The profile data for the NSC & P-65 rails were processed and are listed in Tables 1 and 2, respectively. Figures 1 and 2 identify the locations of the various wear measurement points in these Superrail and P-65 rail test sites.

These final profile measurements verify the long-term stability of the NSC Superrail, Russian P-65 rail and control Algoma 1% Cr rail wear rates. Detailed monitoring of these test sites has been discontinued.

AWC LOW ALLOY RAIL

Test strings of the AWC low alloy test rails manufactured by Algoma Steel were installed, along with NSC Superrail, for in-service comparative wear testing at MP 60.3 on the Shuswap Subdivision in December 1985. Initial rail profile measurements were performed at selected wear measurement points on these test strings in November 1985 at the Transcona Rail Yard.

RAIL PROFILOMETER CLAMP

An improved mounting system for the Research and Development Department's rail profilometer was developed in March 1986.

Table 1

Cumulative Wear Data for Japanese Superrail Test Site #2: MP 102.1, Thompson Subd.

Meas. Point & Description*	Wear Indice	Cumulative Tonnage (MGT)					
		0 (Ref.)	27.4	67.1	88.2	113.2	138.0
1, HCr (3 1/2°)	Vertical (in.)	0	.016	.031	.028	.040	.051
	Gauge Face (in.)	0	0	.039	.074	.112	.126
	Total Area (sq. in.)	0	.022	.083	.128	.181	.212
2, LCr (3 1/2°)	Vertical (in.)	0	.008	.024	.035	.052	.063
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.016	.033	.068	.091	.120
3, HJ (3 1/2°)	Vertical (in.)	0	0	0	.012	.016	.024
	Gauge Face (in.)	0	0	0	.020	.044	.055
	Total Area (sq. in.)	0	.007	.027	.086	.116	.137
4, LJ (3 1/2°)	Vertical (in.)	0	.016	.016	.028	.036	.039
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.019	.024	.049	.071	.075
5, LJ (6 1/2°)	Vertical (in.)	0	.012	.031	.039	.056	.063
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.031	.079	.096	.125	.145
6, HJ (6 1/2°)	Vertical (in.)	0	0	.028	.024	.028	.039
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.011	.066	.073	.105	.235
7, LCr (6 1/2°)	Vertical (in.)	0	.028	.087	.110	.168	.220
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.051	.170	.214	.345	.481
8, HCr (6 1/2°)	Vertical (in.)	0	.024	.039	.055	.068	.091
	Gauge Face (in.)	0	.020	.020	.039	.084	.110
	Total Area (sq. in.)	0	.045	.076	.124	.196	.268
9, HCr (8 1/2°)	Vertical (in.)	0	.024	.059	.067	.088	.110
	Gauge Face (in.)	0	0	.059	.083	.136	.150
	Total Area (sq. in.)	0	.049	.158	.202	.307	.379
10, LCr (8 1/2°)	Vertical (in.)	0	.039	.071	.110	.160	.185
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.070	.139	.214	.323	.409
11, HJ (8 1/2°)	Vertical (in.)	0	0	.016	.020	.032	.039
	Gauge Face (in.)	0	0	0	.028	.056	.063
	Total Area (sq. in.)	0	.021	.071	.104	.159	.175
12, LJ (8 1/2°)	Vertical (in.)	0	.024	.039	.043	.072	.083
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.045	.083	.090	.146	.162

Table 1 (Cont'd.)

Cumulative Wear Data for Japanese Superrail Test Site #2: MP 102.1, Thompson Subd

Meas. Point & Description*	Wear Indice	Cumulative Tonnage (MGT) 0 (Ref.)	27.4	67.1	88.2	113.2	138.0
13, LJ	Vertical (in.)	0	.008	.020	.020	.036	.043
(4 1/2°)	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.006	.030	.037	.063	.083
14, HJ	Vertical (in.)	0	.008	.012	.016	.024	.028
(4 1/2°)	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.027	.044	.065	.103	.110
15, LCr	Vertical (in.)	0	.024	.055	.063	.080	.102
(4 1/2°)	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.082	.088	.099	.146	.194
16, HCr	Vertical (in.)	0	.008	.031	.031	.044	.059
(4 1/2°)	Gauge Face (in.)	0	0	0	.020	.036	.047
	Total Area (sq. in.)	0	.015	.055	.073	.120	.144
17, LCr	Vertical (in.)	0	.028	.094	.118	.160	.177
(6 1/2°)	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.033	.160	.224	.311	.366
18, HCr	Vertical (in.)	0	.020	.047	.055	.072	.083
(6 1/2°)	Gauge Face (in.)	0	.024	.047	.083	.148	.177
	Total Area (sq. in.)	0	.059	.129	.171	.270	.323
19, LJ	Vertical (in.)	0	.016	.043	.047	.060	.071
(6 1/2°)	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq. in.)	0	.018	.078	.082	.104	.140
20, HJ	Vertical (in.)	0	0	.020	.055	.058	.035
(6 1/2°)	Gauge Face (in.)	0	0	.020	.055	.108	.126
	Total Area (sq. in.)	0	.019	.079	.126	.178	.213

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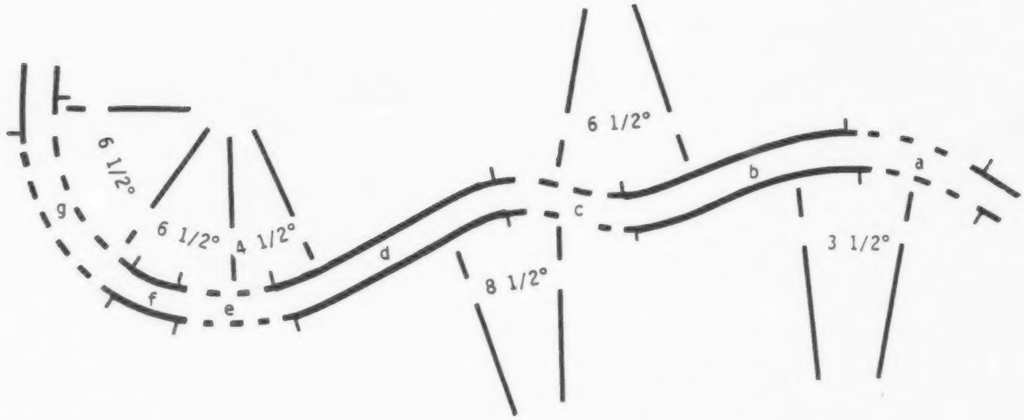
* The following abbreviations designate the rail position and type particular to each measurement point:

HCr/LCr = Algoma 1% Cr rail on high/low rail of curve
HJ/LJ = NSC Superrail on high/low rail of curve

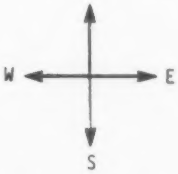


Mile 102.1-103.1
Thompson Subdivision

Lubricators:
north rail - MP 93.3
& 105.1
south rail - MP 102.3

Japanese Superrail ——

Algoma 1% Cr Rail - - -



Mark	Jap. Superrail North	Jap. Superrail South	Algoma Cr North	Algoma Cr South	Change-Over and Measurement Pts.	
a			555'	558'	1	1-4
b	956'	955'			2	5-8
c			873'	872'	3	9-12
d	1052'	1053'			4	13-16
e			1059'	1029'	5	17-20
f	647'	679'			--------	
g			834'	624'		

Figure 1: Track Layout with Curvatures and Location of Change-Over/Measurement Points for Japanese Superrail Test Site #2: MP 102.1, Thompson Sud.

Table 2

Cumulative Wear Data for Russian P-65 Rail Test Site #2: MP 87.7, Thompson Subd.

Measurement Point and Description*	Wear Indice	Cumulative Tonnage (MGT's)						
		Ø (Reference)	27.1	40.8	48.4	72.9	96.0	197.6
1, tangent Cr	Vertical (in)	0	.025	.037	-	.056	.072	.10
	Gauge Face (in)	0	0	0	-	0	0	0
	Total Area (sq.in)	0	.025	.050	-	.083	.107	.218
7, HCr	Vertical (in)	0	.020	.043	-	.055	.055	.23
	Gauge Face (in)	0	.051	.063	-	.098	.098	.213
	Total Area (sq.in)	0	.093	.142	-	.202	.232	.710
9, HCr	Vertical (in)	0	.024	-	.024	.059	.063	.22
	Gauge Face (in)	0	.059	-	.075	.114	.118	.215
	Total Area (sq.in)	0	.098	-	.137	.229	.248	.68
10, LCr	Vertical (in)	0	.028	.047	-	.079	.091	.200
	Gauge Face (in)	0	.016	0	-	0	0	0
	Total Area (sq.in)	0	.048	.080	-	.147	.162	.34
11, HP65	Vertical (in)	0	.012	-	.028	.039	.059	.200
	Gauge Face (in)	0	.024	-	.051	.087	.102	.22
	Total Area (sq.in)	0	.088	-	.132	.184	.245	.65
12, LP65	Vertical (in)	0	.028	-	.043	.067	.079	.14
	Gauge Face (in)	0	0	-	0	0	0	0
	Total Area (sq.in)	0	.052	-	.099	.139	.160	.310
13, HP65	Vertical (in)	0	.008	-	.028	.039	.051	.17
	Gauge Face (in)	0	.051	-	.059	.091	.102	.188
	Total Area (sq.in)	0	.094	-	.133	.191	.221	.555
19, tangent P65	Vertical (in)	0	.020	-	.020	.028	.043	.08
	Gauge Face (in)	0	0	-	0	0	0	0
	Total Area (sq.in)	0	.051	-	.055	.073	.098	.24
24, HP65	Vertical (in)	0	.008	-	.031	.047	.063	.188
	Gauge Face (in)	0	.047	-	.071	.079	.075	.138
	Total Area (sq.in)	0	.088	-	.162	.203	.236	.54
25, LP65	Vertical (in)	0	.031	.051	-	.063	.091	.168
	Gauge Face (in)	0	0	0	-	0	0	0
	Total Area (sq.in)	0	.067	.106	-	.133	.193	.34
26, HP65	Vertical (in)	0	.035	.055	-	.055	.071	.18
	Gauge Face (in)	0	.059	.071	-	.079	.087	.18
	Total Area (sq.in)	0	.151	.200	-	.210	.259	.615

Table 2 (Cont'd.)

Cumulative Wear Data for Russian P-65 Rail Test Site #2: MP 87.7, Thompson Subd.

Measurement Point and Description*	Wear Indice	Cumulative Tonnage (MGT's)						
		0 (Reference)	27.1	40.8	48.4	72.9	96.0	197.6
27, LCr	Vertical (in)	0	.025	.064	-	-	-	.175
	Gauge Face (in)	0	0	0	-	-	-	0
	Total Area (sq.in)	0	.050	.122	-	-	-	.353
28, HCr	Vertical (in)	0	.020	.028	-	.047	.071	.213
	Gauge Face (in)	0	.075	.087	-	.091	.098	.163
	Total Area (sq.in)	0	.093	.125	-	.164	.222	.599

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* The following abbreviations designate the rail position and type particular to each measurement point:

HCr/LCr = Algoma 1% Cr rail on high/low rail of curve
HP65/LP65 = Russian P-65 rail on high/low rail of curve

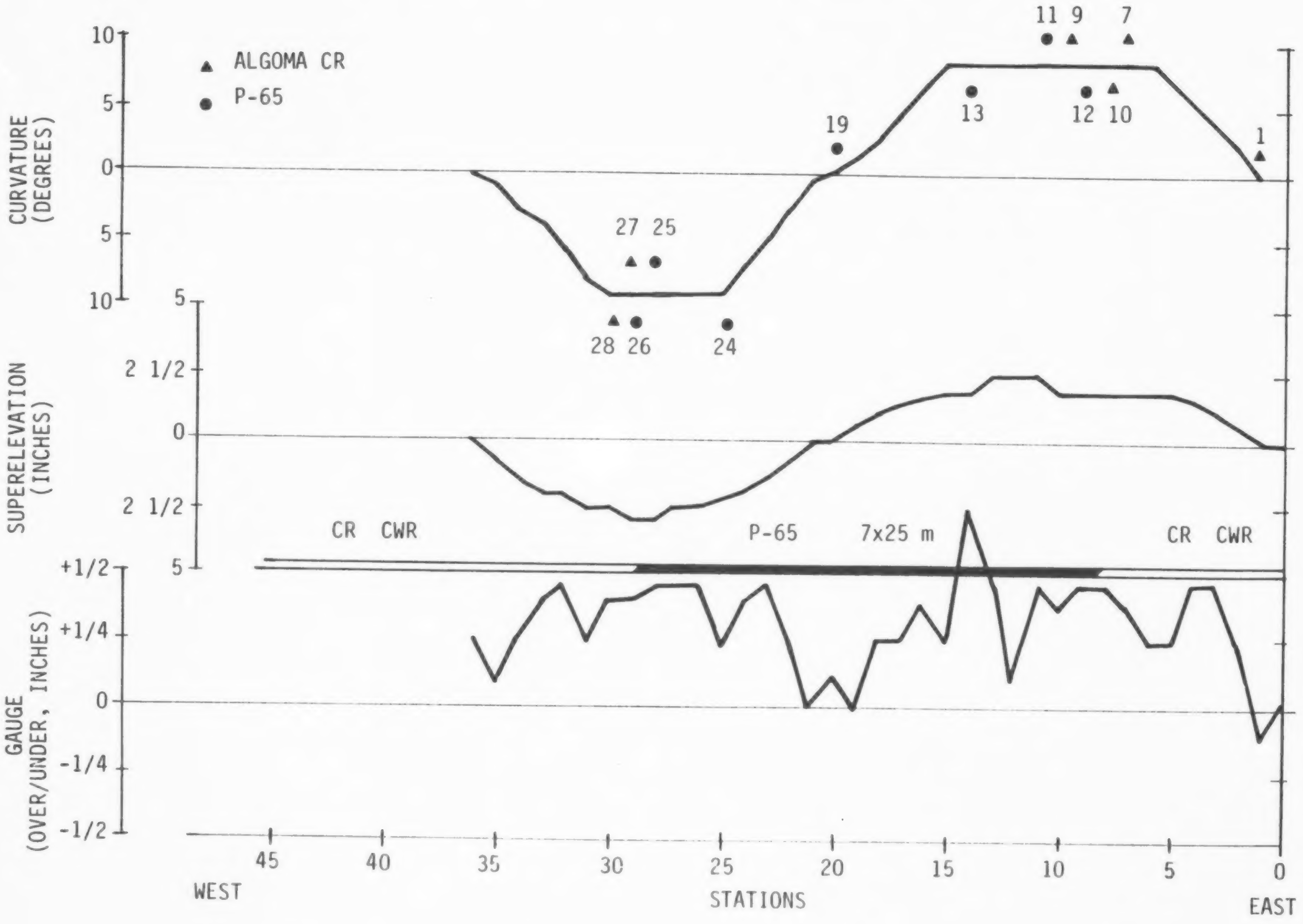

Figure 2: Curvature, Superelevation, Gauge and Location of Measurement Points For Russian P-65 Rail Test Site #2: MP 87.7, Thompson Subdivision

TESTING OF PACT SLAB, MILE 106.1
MOUNTAIN SUBDIVISION (ALBERT CANYON)

Research and Development
CP Rail
Montreal

EXECUTIVE SUMMARY

The PACT (Paved Concrete Track) at Mile 106.1 on the Mountain Subdivision is a test installation constructed to evaluate the suitability of the PACT system for C.P. Rail's conditions of climate and loading. The site is close to the Rogers Pass tunnel location and was selected to resemble as closely as possible the conditions in and around these tunnels, which would be the primary location for use of this track system.

Various measurements and observations need to be made to allow proper evaluation of the PACT system's performance.

These include:

- measurement of rail levels, alignment and gauge
- inspection of cracks in slab, and separation of track and base slabs
- measurement of vertical deflection of the track slab under live load
- inspection of rails for wear and defects
- measurement of rail pad compression under live load
- inspection of pads, clips, insulators and shoulders for any developing problems

These measurements will allow the slab designers to evaluate the appropriateness of the design for local conditions and operating personnel to examine the system's effect on maintenance of track geometry and on wear and damage of track hardware.

The first set of measurements was obtained in November, 1984 and were subsequently reported in the 1984 Track/Train Dynamics Report. Subsequent tests were conducted in March '85, May '85, August '85 and May '86, and those results are presented here. A final evaluation test of the slab is scheduled for September, 1986.

SOMMAIRE

Le PACT (Plate-forme ferroviaire en béton) au millage 106.1 dans la subdivision Mountain, est un prototype construit dans le but d'évaluer l'aptitude du système PACT aux conditions de climat, et de chargement du CP Rail. Le site est proche du tunnel du Roger's Pass, où sera installé le premier système PACT, et a été choisi pour présenter le mieux possible les conditions existantes à l'intérieur et aux environs de ce tunnel.

Il faut effectuer plusieurs mesures et observations pour être en mesure d'évaluer correctement la performance du système PACT. Cela comprend:

- mesure du niveau, de l'alignement et de l'écartement des rails
- inspection de la dalle pour les fissures et la séparation entre la dalle de voie et la dalle de base
- mesure de la déflexion verticale de la dalle de voie due à la charge vive
- inspection des rails pour des défauts et des fissures
- mesure de la compression des semelles élastiques due à la charge vive
- inspection des semelles élastiques, des attaches, des isolateurs et des épaulements d'attache.

Ces mesures vont permettre aux concepteurs de plates-formes en béton d'évaluer la crédibilité de la conception pour les conditions locales.

Ces mesures aideront aussi les personnes concernées par l'entretien de la voie d'examiner l'effet du système sur le maintien de la géometrie de la voie ainsi que l'usure et les dégâts du système de fixation des rails.

Le premier ensemble de mesures a été obtenu en novembre 1984 et, par la suite, presenté dans le rapport de 1984 sur les interactions dynamiques roue-rail. Depuis, quatre essais additionnels de la dalle ont été effectués et ces résultats sont presentés ici. Il est planifié d'effectuer une autre évaluation de la dalle en septembre 1986.

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TESTING OF PACT SLAB, MILE 106.1
MOUNTAIN SUBDIVISION (ALBERT CANYON)

TEST 2

P.C. Ireland
K. Griffin

Research and Development
CP Rail
Montreal

This report presents the results of the second in a series of tests being carried out by the Planning and Research Department to determine the suitability of the PACT (Paved Concrete Track) for the climatic and loading conditions particular to the Pacific Region of CP Rail.

This second test was performed between February 27 and March 4, 1985. Temperatures during this period fluctuated between a high of 7°C during the day and -15°C during the night.

At the time of testing the PACT had been in service for five months and had experienced approximately 18.8 MGT (essentially loaded unit train traffic).

Large amounts of snow and ice prevented any significant inspection of the concrete slab, rail pads and clips - only the rail head was immediately accessible and an examination of the same was performed and is included. Table 1 details the rail pad compression and slab vertical deflections.

In the spring, when the PACT is clear of snow, a thorough inspection of the entire system will be made. Test cylinders which have been curing in the same environment as the slab will be located and sent for strength testing. The third test is tentatively scheduled for the end of May 1985.

Table 1 - Maximum Rail Pad Compression and Slab Vertical Deflections (Test 2)

Location		Train	Train	Slab	Pad Compression	
Clip No.	Side	Type	Speed(mph)	Deflection	Gauge	Field
0	low	coal	25	0.79	0.38	0.47
	high	sulphur	19	0.60	0.38	0.43
450	low	grain	20	0.54	0.46	0.94
	high	grain	22	0.83	0.26	0.50
470	low	grain	25	0.56	0.38	0.39
	high	potash	25	0.56	0.54	-
922	low	coal	15	1.40	0.25	0.59
	high	coal	25	1.27	0.24	0.50

Note: All compression and deflection measurements are in millimetres.

High Rail

While the rail appears to be well lubricated, there is considerable wheel squeal with the passage of each loaded train over the PACT. Head checks (small micro-cracks due to surface thermal fatigue, approximately 1/4" long and 8/running inch) are all along the gauge corner; these cracks reflect the high-pitched squeal heard during curving and may correspond to the increased stiffness of rails on the slab section. These head checks do not present an operating hazard.

Plastic flow increases slightly in the heat-affected-zone (HAZ) about welds, and decreases slightly within the weld zone. A small plastic flow lip is present along the gauge face of the rail, down approximately 5/8 inch from the running surface. The wear path is very stable and is offset towards the gauge side of the rail; the outer 3/4 inch of the high rail running surface has experienced no wear. Only a very small amount of wear (gauge face and vertical) has been experienced to date. The plastic flow and wear exhibited by these high rails are consistent with the limited traffic over the PACT.

Low Rail

Low rails also appear to be adequately lubricated. Slight plastic flow lips are evident on both sides of the rail running surface; the plastic flow variation from base rail metal : HAZ : weld zone is consistent with that observed for high rails. There are no visible corrugations or shells.

The wear path is very stable throughout, occupying approximately the central (slightly offset towards the field side of the rail) 1 1/2 inches of the rail running surface in the spiral into the curve, and widening to occupy the central +2 inches within the fully developed section of the curve.

There are early indications of rail squats (i.e. Japanese black spots) located in the middle of the low rail running surface. These discolorations are approximately 1/2 inch in diameter and number 4-6/running foot within the fully developed portion of the curve. They decrease in frequency to 2-3/running foot within the spiral section, 1-2/running foot within the transitionary concrete tie zone at each end of the PACT and do not continue for any distance into the regular track sections. These "defects" do not pose any immediate operating hazard, but should be monitored. The PACT is scheduled to be ground in late April 1985, and at regular intervals thereafter, at the request of the Engineering Department of CP Rail. It is expected that the above grinding operation(s) will remove the noted rail head discolorations.

TESTING OF PACT SLAB, MILE 106.1
MOUNTAIN SUBDIVISION (ALBERT CANYON)

TEST 3

P.C. Ireland
B. de Josez

Research and Development
CP Rail
Montreal

1.0 Introduction

This report presents the results of the third in a series of tests being carried out by the Planning and Research Department to determine the suitability of the PACT (Paved Concrete Track) for the climatic and loading conditions particular to the Pacific Region of CP Rail.

This test was performed between May 13 and May 23, 1985. Measurements were taken at temperatures hovering about 25° C.

At the time of testing, the PACT had been in service for eight months and has experienced approximately 30.5 MGT (essentially loaded unit train traffic).

A variety of measurements were performed to evaluate the overall condition of the PACT. Monitoring exercises performed by the department included vertical deflection and rail pad compression measurements, a crack survey and a general inspection of the entire fastening system and rail pads. Representatives of Pandrol Canada Ltd. took toe load measurements at selected points throughout the slab. Concrete cylinder strength tests were performed by the Special Projects Test Lab at Glacier. In addition, a survey team from Special Projects did elevation checks at 50 metre intervals. A weather summary for each month since the PACT was constructed is included as an appendix. No evaluation of the rail was possible due to recent grinding operations.

2.0 Test Results and Observations

2.1 Vertical Displacement and Pad Compression

Measurement of slab deflections and pad compression were done at the same locations as previous tests and with the same procedures. In addition, the vertical displacement of the first concrete tie at the west end was measured. For each test run, the maximum value from the data was extracted and these results are presented in Table 1.

Table 1 - Maximum Rail Pad Compression and Slab Vertical Deflections (Test 3)

Location Clip No.	Side	Train Speed (mph)	Slab Deflection (mm)	Pad Compression (mm) Gauge	Field
Concrete tie #1	Low	22	1.6	-	-
0	Low	18	1.9	0.10	0.41
	High	20	0.37	0.21	0.82
450	Low	19	0.42	0.13	0.62
	High	19	2.54	0.21	0.56
470	Low	17	1.7	0.21	0.65
	High	18	1.8	0.13	0.68
922	Low	15	1.45	0.27	0.94
	High	17	2.18	0.31	1.03

2.2 Crack Survey

The crack survey is shown in Appendix A. Two kinds of cracks were reported: hairline cracks and visible cracks (represented by a thick line). It was noticed that the latter usually runs transversally through both slabs. Also there seems to be more hairline cracks on the high rail side. A few unexpected longitudinal cracks were emanating from the transversal ones. This can be seen in photo #1. Because these cracks coincide with a longitudinal reinforcement bar installed 40 mm from the surface, water infiltration could be a problem. In future tests, they will be monitored.

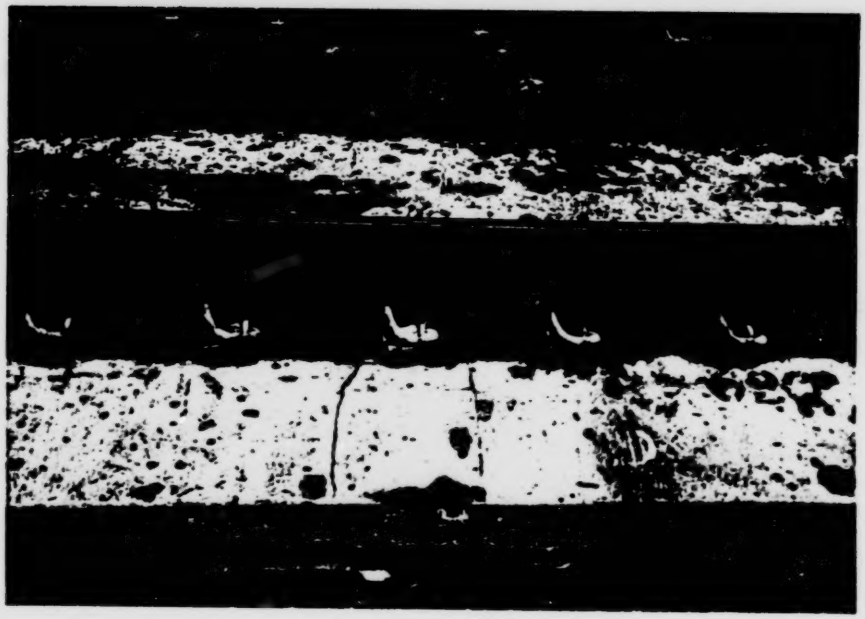


Photo #1 - Longitudinal cracks emanating from a transversal one in the pact slab.

It was very difficult to inspect for separation between the PACT and base slab because of the sealant placed in the high side joint, and the presence of ballast on the low side (see photos #2 and #3), but nothing unusual was noticed.

Compared to the previous crack survey done by Special Projects personnel the number of cracks has increased.

2.3 Survey Data

A survey team from Special Projects measured the elevation of the slab at 50 m intervals. At each section three points were measured: North base slab, center PACT slab and south base slab. These results will be included in the next report.

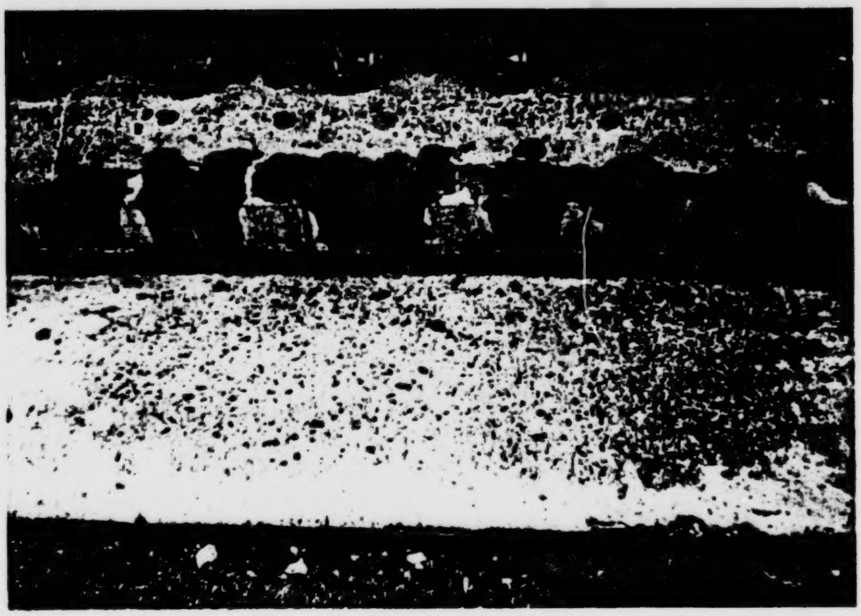


Photo #2 - Sealant placed in the high side joint of the two slabs.

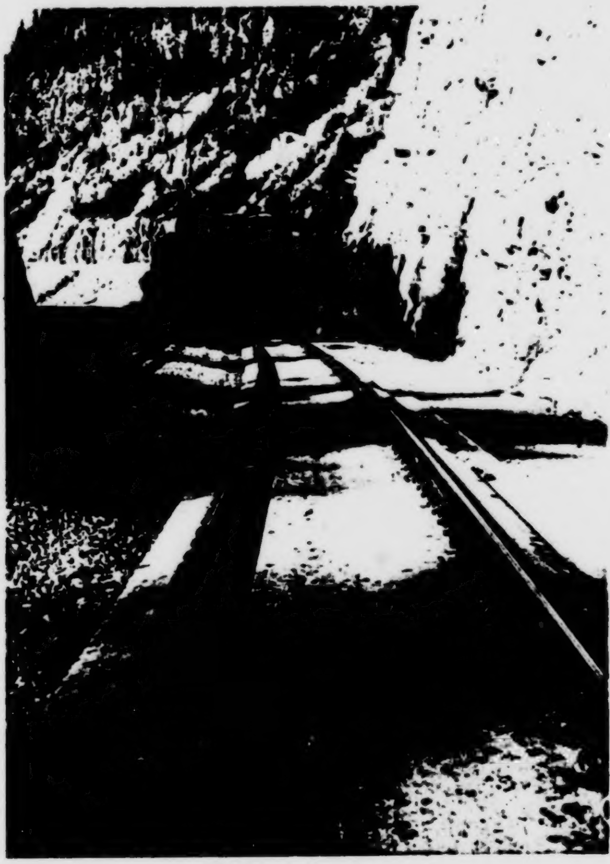


Photo #3 - View of the western half slab showing the presence of ballast in the low rail side.

2.4 Concrete Strength

Testing of concrete cylinders strength was performed by the Special Projects laboratory located at Glacier. The results are given in Table 2. The cylinders were cast September 7, 1984, and tested May 16, 1985.

Table 2 - Concrete Cylinder Strength After Six Months

Location	Compression Strength MPa (psi)
9 + 333	41.91 (6078)
9 + 371	46.77 (6784)
9 + 415	45.12 (6544)
9 + 467	47.02 (6820)
9 + 508	45.56 (6608)
9 + 562	47.26 (6855)

The design strength was originally specified as 30 MPa.

2.5 General Inspection

Pad - The cork pad, placed in the western half of PACT slab, was shredding and cracking in some areas. Nothing similar was noticed in the rubber pad. Lateral displacement of the pads, when existing, generally varied between 3 mm and 6 mm. The worst was 13 mm at clip 730 - low rail - field side, thus exceeding the alignment tolerance of 3 mm specified during construction. Photo #4 shows the condition of the pad at clip 730. This lateral displacement of the pad occurred always on the field side of the rail.

Clip - Clip 695 - high rail - field side was missing. A broken clip was also found near clip 680 - high rail - field side. Two clips had moved out of the shoulder by 20 mm. A few clips were recorded to be rusted.

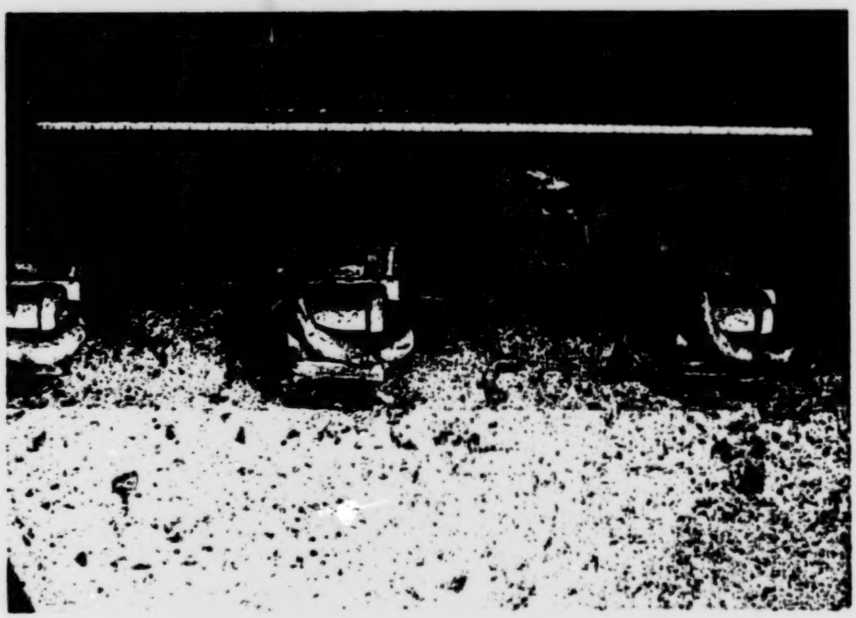


Photo #4 - Lateral displacement of the pad around clip 730.

Slab - Voids appear to have formed under the slab in at least seven locations (clip 90, 130, 184, 227, 289, 336, 410 to 455), as evidenced by cracking of the subgrade and separation from the base slab immediately adjacent to it. The soil condition is shown in photo #5. This problem will require special attention in the future. The concrete is spalling at each end of the slab, and also in a few places in the corner of the PACT slab (50 mm x 50 mm) as can be seen in photo #6.

2.6 Weather Summary

A weather report is given in Appendix B for the months of September 1984 through April 1985. During this period of time, the maximum temperature was 15°C and the minimum -23°C. It should be noted that the temperatures reported are warmer than those experienced by the Albert Canyon slab because the weather station is located at a lower elevation.

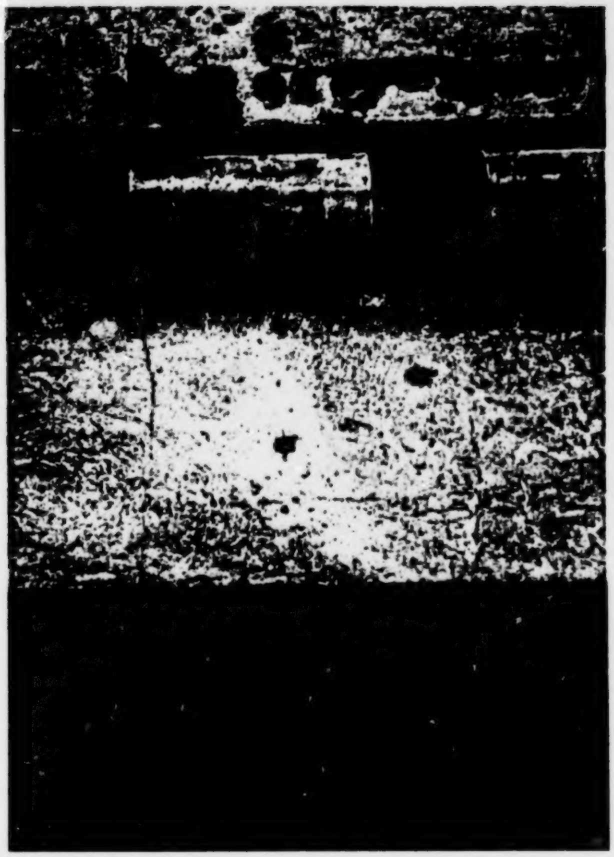


Photo #5 - Soil Condition at a pumping slab location.

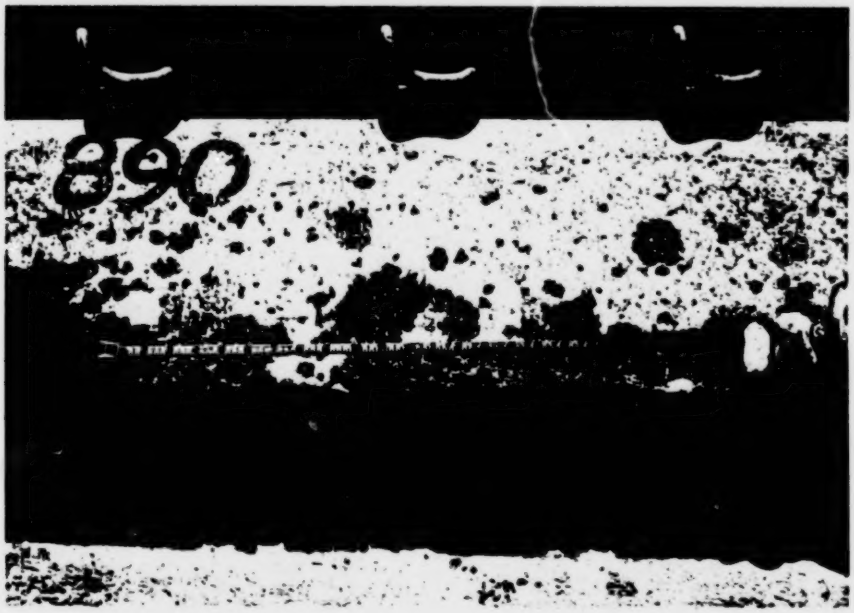


Photo #6 - Spalling of the concrete in the corner of the PACT slab.

3.0 Conclusions

The maximum slab vertical displacement measured was 2.54 mm, which is the highest value recorded to date. This deflection (the maximum expected from design calculations is 1.1 mm) measured at clip 450 can be related to the soil condition at this location. The presence of voids underneath the slab can cause higher deflections and hence higher stresses than expected. In future tests, attempts will be made to infer the quality of the subgrade along the entire length of the slab.

The small values of pad compression can be attributed to a permanent set of the pad which would increase its stiffness. The pad thickness will be measured during the next test.

In addition, cracks, ponding of water on the surface of the slab and deterioration of the sealant will be very closely watched, as they are considered to be potential sources of problems.

The fourth test is tentatively scheduled for the end of August 1985.

TESTING OF PACT SLAB, MILE 106.1
MOUNTAIN SUBDIVISION (ALBERT CANYON)

TEST 4

P.C. Ireland
B. de Josez

Research and Development
CP Rail
Montreal

1.0 INTRODUCTION

This report presents the results of the fourth test in a series of tests being carried out by the Planning and Research Department to evaluate the PACT for the climatic and loading conditions particular to the Pacific Region of CP Rail.

This test was performed between August 19 and August 24, 1985. Measurements were taken at temperatures hovering about 20°C.

At the time of testing, the PACT had been in service for twelve months and has experienced approximately 37.1 MGT (essentially loaded unit train traffic).

To evaluate the behaviour and condition of the PACT, a variety of monitoring exercises were performed including: dynamic vertical deflection measurements of the PACT and base slab at pumping locations, static vertical deflection measurements of the base slab continuously along its length (northside only), rail pad thickness measurements, inspection of the slab, the rail, the fastening system and the rail pad. In addition, concrete cylinder strength tests were performed by the Special Projects Test Lab at Glacier. All the results of these monitoring exercises are presented in this report.

2.0 TEST RESULTS AND OBSERVATIONS

2.1 Vertical Displacement

Measurement of slab deflections were taken at two locations where the slab seems to be pumping (Clip 184 and 336). This was done with the same procedure used in previous tests. In addition to the PACT deflection, the base slab deflection was measured, at the same location, for comparison. The locations of the target for these measurements are shown in Figure 1. The maximum deflections occurred during the passage of the locomotives and these results are presented in Table 1.

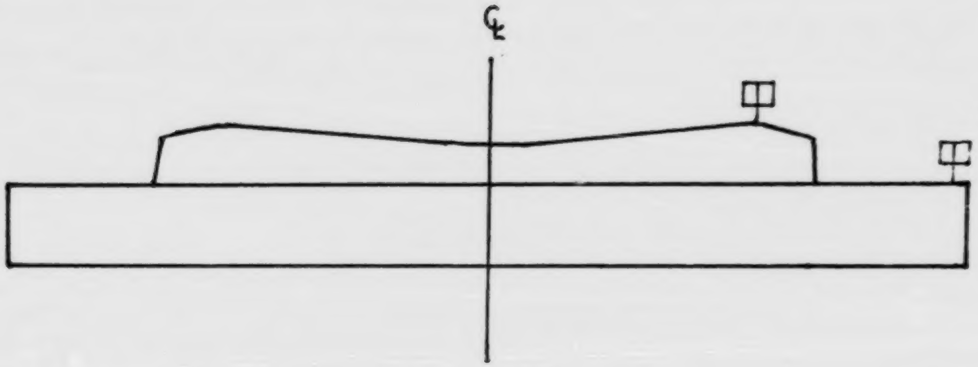


FIGURE 1: Locations of the target for the dynamic measurements of the PACT and base slab deflection

TABLE 1 - Slab Vertical Deflections (Test 4)

Clip No.	Side	Location	Train Speed (mph)	Slab Deflection (mm)
184	North	PACT	23	0.56
184	North	Base Slab	20	0.50
336	North	PACT	30	0.67
336	North	Base Slab	25	0.53

2.2 Static Vertical Displacement

The static deflection of the north side of the base slab was measured along the length. This was done in an attempt to identify problem areas in the subgrade.

The measurement technique involved using a K & E tilting level equipped with an optical micrometer, and an optical alignment scale. The scale was attached to a range pole which was placed at the measurement location. A zero reading was taken and then a locomotive (CP 5604 - weighing approximately 210 tons) approaching from the east, crawled up to that point. With the middle axle of the front end positioned over the measurement point a second reading was taken. The difference between the two readings gives the slab vertical deflection. These results are tabulated in Table 2 and graphed in Figure 2. The south side deflection of the slab was measured at only three points due to the presence of ballast. These results are also presented in Table 2.

TABLE 2 - STATIC DEFLECTION OF THE BASE SLAB

NORTH SIDE	Clip No.	Deflection (mm)
	3	0.23
	20	0.28
	50	0.15
	80	0.33
	110	0.15
	140	0.28
	170	0.30
	200	0.25
	230	0.30
	260	0.30
	290	0.41
	320	0.48
	335	0.51
	350	0.25
	380	0.13
	410	0.25
	440	0.23
	470	0.43
	500	0.30
	530	0.33

NORTH SIDE (cont'd.)	Clip No.	Deflection (mm)
	560	0.33
	590	0.30
	620	0.20
	650	0.25
	665	0.28
	680	0.25
	695	0.33
	710	0.30
	740	0.41
	755	0.33
	770	0.38
	800	0.48
	830	0.33
	860	0.41
	890	0.46
	920	0.20

SOUTH SIDE	Clip No.	Deflection (mm)
	200	0.28
	560	0.30
	890	0.28

2.3 Pad Thickness

The pads seem to have adopted a permanent set, therefore their thickness were measured along the slab using a telescoping gauge and a micrometer. The results are presented in Table 3. The design pad thickness was 10 mm. From these measurements the following mean values (see Table 4) were obtained:

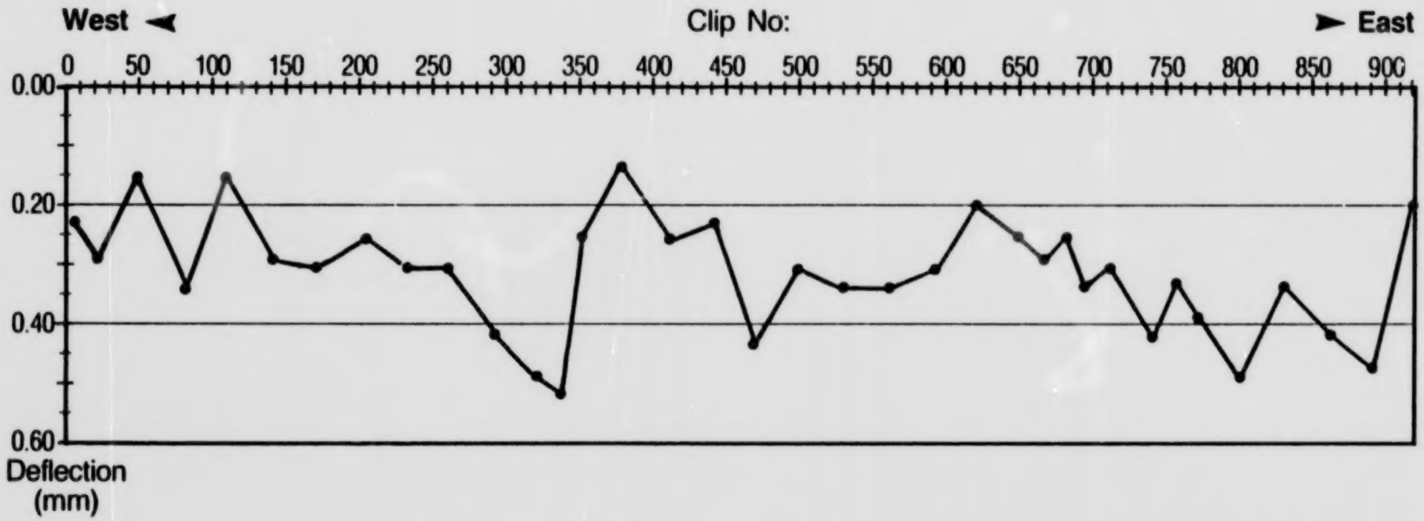


FIGURE 2: Static Deflections Along the Base Slab

TABLE 3 - PAD THICKNESS

HIGH RAIL	Clip No.	Width (mm)	Clip No.	Width (mm)
	918	9.271	548	8.306
	908	9.017	541	8.357
	894	8.890	527	8.255
	888	8.636	521	8.509
	881	8.687	507	8.865
	874	9.246	480	8.865
	868	8.128	467	8.915
	848	8.966	460	8.763
	820	8.687	416	7.823
	808	8.636	393	7.696
	788	8.763	373	7.645
	767	8.966	353	7.544
	760	9.627	333	7.544
	748	8.509	225	7.569
	728	8.128	205	7.671
	720	8.306	185	7.874
	708	8.407	165	7.620
	701	8.839	145	7.696
	688	8.509	125	8.509
	680	8.992	93	7.976
	660	9.246	66	7.722
	640	7.620	53	7.620
	627	8.611	46	7.544
	621	9.144	32	8.280
	588	9.144	27	8.255
	581	8.941	14	7.976
			7	7.569

LOW RAIL	Clip No.	Width (mm)	Clip No.	Width (mm)
	899	8.788	158	9.128
	892	8.255	114	8.334
	876	8.865	66	7.937
	845	8.585	23	7.937
	825	8.636	2	9.128
	798	8.839		
	785	8.992		
	765	8.509		
	758	8.458		
	738	8.585		
	718	8.255		
	698	8.890		
	691	8.433		
	671	8.814		
	644	8.382		
	568	8.382		
	535	7.874		
	511	7.874		
	493	9.398		
	476	8.509		
	463	9.271		
	445	8.731		
	422	7.937		
	391	7.541		
	342	8.731		
	303	7.541		
	250	7.937		
	213	7.937		

TABLE 4 - MEAN VALUES OF PAD THICKNESS

	Thickness (mm)	
	High Rail	Low Rail
Rubber Pad	8.7	8.6
Cork Pad	7.8	8.2

2.4 Concrete Strength

Testing of concrete cylinder strength was performed by the Special Projects laboratory located at Glacier. The cylinders were cast September 7, 1984, and tested August 20, 1985. The results are presented in Table 5.

TABLE 5 - CONCRETE CYLINDER STRENGTH AFTER ONE YEAR

Location	Compression Strength	
	MPa	(psi)
9 + 316	39.9	(5795)
9 + 354	45.8	(6643)
9 + 391	49.2	(7138)
9 + 445	51.6	(7491)
9 + 489	44.8	(6502)
9 + 537	44.3	(6431)

2.5 General Inspection

Except for Clips 253 and 501 - low rail - field side - that were out by 20 mm, nothing abnormal was noticed in the fastening system or in the pads.

A few additional cracks were observed along the slab and are added to the last crack survey in Appendix A. A major crack coinciding with a pumping location and a construction joint (Clip 797 - HR - Base slab) appears to have widened. This crack runs transversally through both slabs. This will be watched in future tests.

Heavy rain during the first two days of the test showed that water ponds all along the base slab near the junction with the PACT, and on the PACT generally near the low rail.

New pumping locations, in addition to those previously reported, were observed on the north side (i.e. high rail side) at clip 530, 600, 792, 822, 832, 842, 858, 865 to 875 and 882. These locations were noticed due to the presence of fines in the subgrade adjacent to the base slab, and some voids between the base slab and the adjacent subgrade.

2.6 Rail Evaluation

A 15 mph slow order has been in effect from MP 101.6-104.4 and at MP 107.0 (the PACT is located at MP 106.0) since April 1985 to facilitate nearby construction work. Westbound trains are passing over the PACT at 20-25 mph -- well below the balance speed. Also, the PACT rails were ground in April 1985.

High Rail

As noted in March 1985, this rail is well lubricated and exhibits a very stable wear path with minimal plastic flow -- due at least in part to the April 1985 grinding operation. Residual grinding marks are still visible on the field side of the rail running surface where wheel/rail contact does not typically occur.

The central region of the rail running surface, which typically experiences little plastic flow, is characterized by an approximately 1/2" wide, longitudinal, dark band. This dark band (not the grease band) is continuous throughout the fully developed curve section of the PACT, but breaks down in the eastern spiral and tangent sections (see Figure 3). These sections should be monitored to determine the significance, if any, of this phenomenon.

Low Rail

Low rails are also well lubricated and exhibit a stable running band with little plastic flow. There are no visible corrugations or large shells. The outer (i.e. towards field side) 1" of the running band in the fully developed curve section of the PACT has an extensive thermal crack network -- as shown in Figure 4. It is felt that this low rail thermal cracking is largely due to the reduced (i.e. below balance) speed of trains as they pass over the PACT. This situation, while not abnormal, has already led to slight shelling at some low rail weld joints and should be monitored -- such cracking may precede the formation of shelly rail and corrugations.

The indications of rail squats first noted in March 1985, and subsequently removed by grinding in April 1985, were not observed.

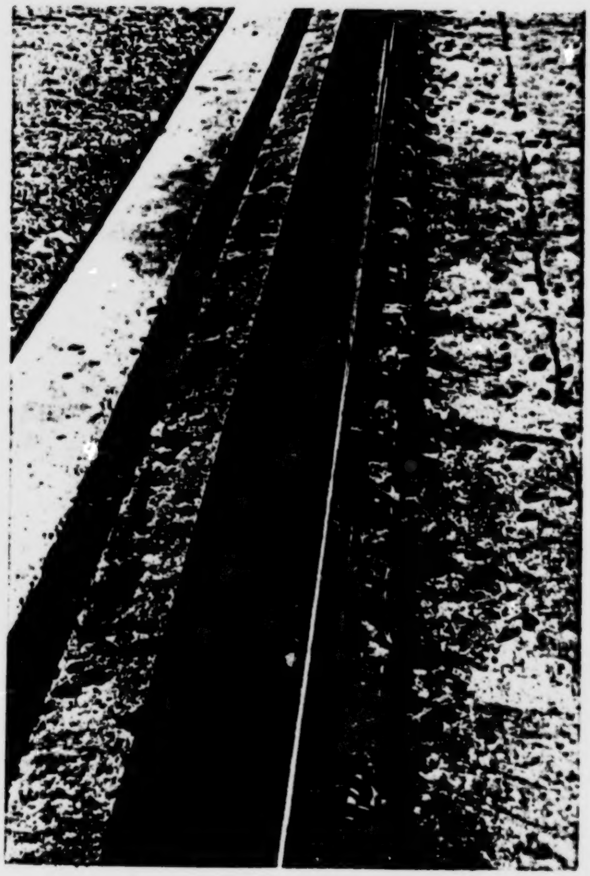


FIGURE 3: Periodic Dark Markings Observed on Spiral/Tangent section of PACT

FIGURE 4: Thermal Crack Network Observed on Low Rail in Fully Developed Curve

3.0 CONCLUSIONS AND RECOMMENDATIONS

With the results obtained from this fourth test the following conclusions and recommendations can be drawn.

- Although deflection measurements of the PACT were taken at two apparent pumping locations, the values obtained were within the permissible design limit of 1.1 mm and were also lower than the deflection values measured in previous tests.

- The highest static deflection was 0.51 mm, measured at clip 335. This coincides with a pumping location. The low and similar values of deflection obtained along the length of the slab do not indicate any significant variation in the subgrade from one point to another.

- The rubber pad settlement is about 1.4 mm. For the cork pad, this value reaches 2.2 mm. This is a very important factor to consider in future design since a significant settlement of the pads could result in an increased stiffness and a reduced ability to attenuate dynamic wheel forces.

- Water is ponding on the base slab. Penetration of water into the PACT/base slab juncture could result in serious problems.

- Monitoring of the PACT rails should continue at periodic (e.g. 3-4 month) intervals.

TESTING OF PACT SLAB, MILE 106.1 MOUNTAIN SUBDIVISION (ALBERT CANYON)

TEST 5

P.C. Ireland
B. de Josez

Research and Development
CP Rail
Report No. T-920-86
May, 1986

1.0 INTRODUCTION

The Research and Development Department conducted the fifth inspection on the PACT on May 5, 6 and 7, 1986. This was done as part of a continuing programme to evaluate the PACT for the climatic and loading conditions particular to the Pacific Region of CP Rail. The results of this inspection are presented in this report.

At the time of the inspection, the PACT had been in service for 19 months and has experienced approximately 75.2 MGT.

To evaluate the behaviour of the PACT the following exercises were conducted:

- rail pad thickness measurements
- slab, fastening system and rail inspection.

Pad measurements were taken at temperatures hovering about 10°C.

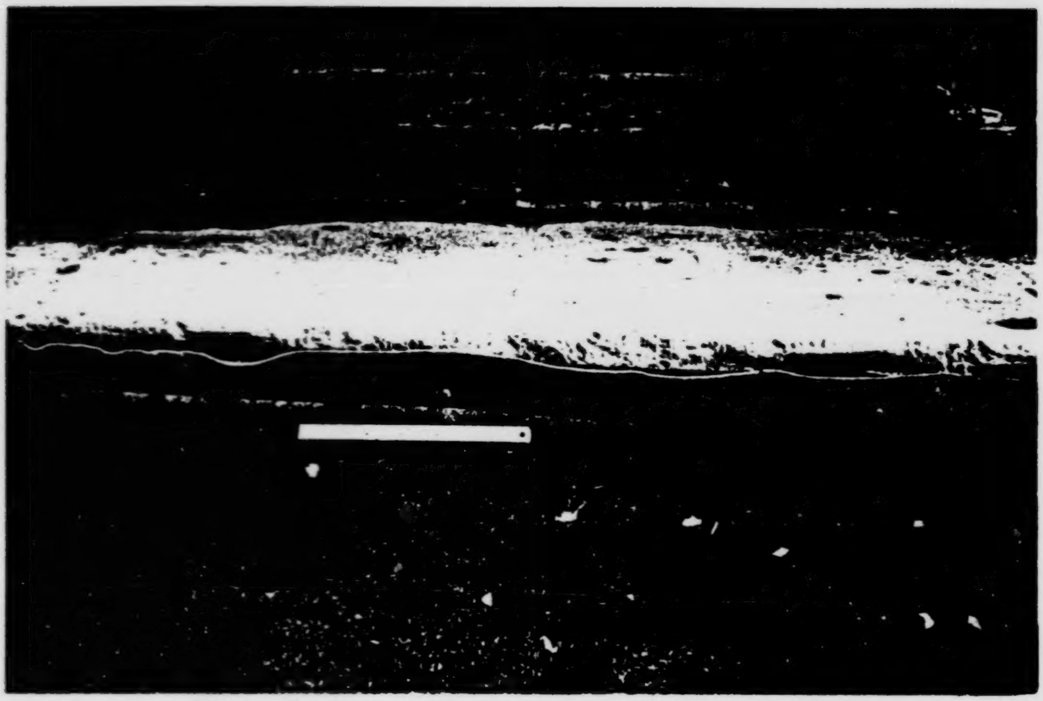
Presently it is planned to conduct one further inspection of the PACT in September 1986. This will mark 2 years that the PACT has been in operation.

2.0 SUBGRADE PROTECTION

As noted in previous inspections of the PACT, the evidence of pumping action was of major concern. In an effort to improve the situation, Special Projects has done some work to facilitate water drainage away from the PACT. On the north side, they have installed a "curtain" that will prevent rainwater from directly penetrating the base slab-soil boundary. This curtain is composed of a butyl rubber sheet sandwiched between two pieces of filter cloth. It extends the length of the PACT and is approximately one and a half metres wide. It has been bolted onto the side of the base slab and the joint is sealed with silicone caulking. See Figures 1 (a) and (b).

The purpose of the filter cloth sandwich is to help prevent the rubber sheet from being punctured. In addition, a sand base was laid down underneath and a sand and gravel base will be added on top (work that commenced last fall had to be halted due to weather and is presently being completed).

The drainage ditch on the north side was improved and an outlet was dug to connect with a nearby river. It appears to have vastly improved the situation as even after heavy rainfalls the water drains away quickly.



(a)

(b)

Figure 1: PACT With Rubber and Filter Cloth Curtain Attached to North Side

3.0 RAIL EVALUATION

No major problems were noted with either the high or low rail. Rail grinding operations had taken place during the last week in April - a week before our inspection. This is the second time that the PACT rails have been ground. The first time was in October 1985.

The only defect of concern was the fairly severe spalling of the low rail at weld joints. This can be seen in Figure 2.

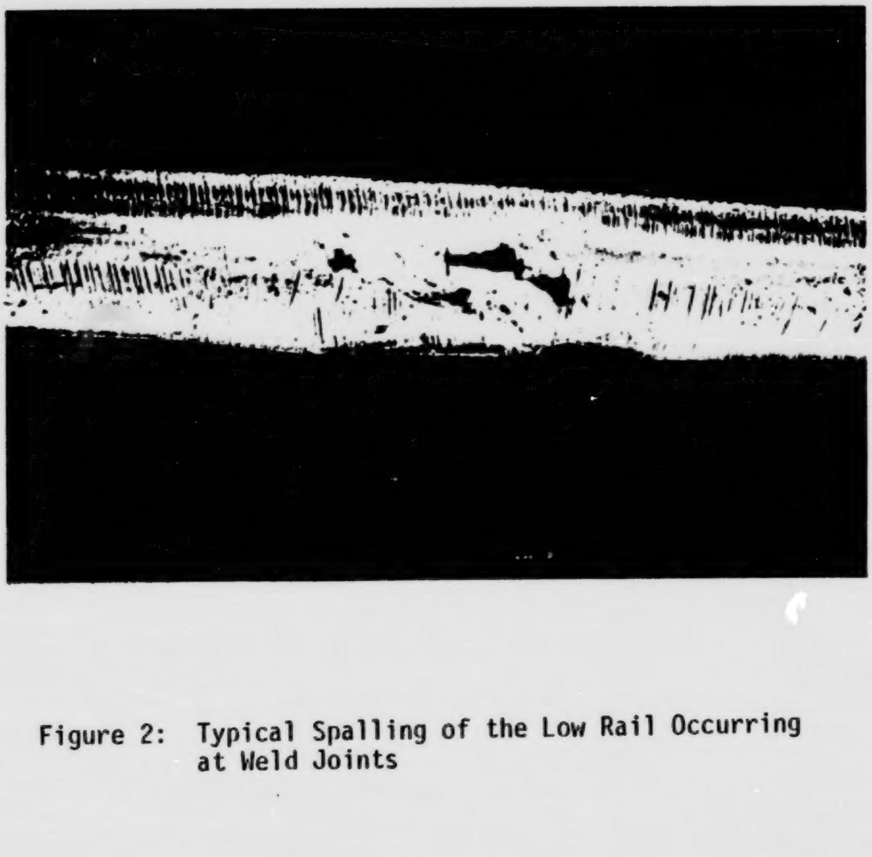


Figure 2: Typical Spalling of the Low Rail Occurring at Weld Joints

4.0 GENERAL SLAB CONDITION

A few additional cracks were observed along the slab and are added to the last crack survey in Appendix A. No major opening of the cracks was observed. Rainwater continues to pond on the north side of the base slab.

The fastening system inspection showed no irregularities.

To measure the pad thickness a telescoping gauge and a micrometer were used. The results are presented in Table 1 and the mean values are given in Table 2. The minimum values of pad thickness found are: 7.671 mm for the rubber pad and 7.595 mm for the cork pad.

These means values are nearly the same as those measured in August 1985. Thus the pad has adopted a permanent set.

A monthly weather summary from May 1985 to March 1986 is presented in Appendix B. During this period of time the maximum temperature was +36.7°C and the minimum -23.6°C.

TABLE 1 - PAD THICKNESS

High Rail

Clip #	Width (mm)
920	9.906
915	9.347
898	8.306
887	8.484
875	9.906
859	8.712
844	8.128
827	8.484
808	8.865
784	8.687
763	8.382
745	9.093
724	9.042
700	8.661
666	8.382
640	8.509
620	8.814
592	8.814
562	7.823
536	7.950
507	9.398
480	8.509
454	7.671
425	7.620
397	7.620
370	7.722
342	8.382
321	8.814
294	8.814
268	7.772
242	8.661
214	7.772
178	8.280
134	8.433
95	8.687
59	7.925
35	7.772
14	8.661

Low Rail

Clip #	Width (mm)
920	7.950
901	8.585
880	7.671
857	8.255
833	8.763
808	8.890
781	8.230
758	7.925
731	8.382
695	8.941
664	9.195
633	8.407
604	8.661
585	9.119
549	8.509
510	7.722
471	8.255
445	7.671
421	8.280
393	7.747
372	7.899
350	8.382
326	8.509
299	7.772
271	7.874
235	8.255
207	7.595
184	7.747
159	7.823
130	8.026
100	7.722
67	8.407
41	7.798
16	8.255

TABLE 2 - MEAN VALUES OF PAD THICKNESS

	Thickness (mm)	
	High Rail	Low Rail
Rubber Pad	8.7	8.4
Cork Pad	8.1	8.0

5.0 CONCLUSIONS

During the fifth inspection of the PACT, no major anomalies were noticed and its over-all condition is basically the same as observed in August 1985.

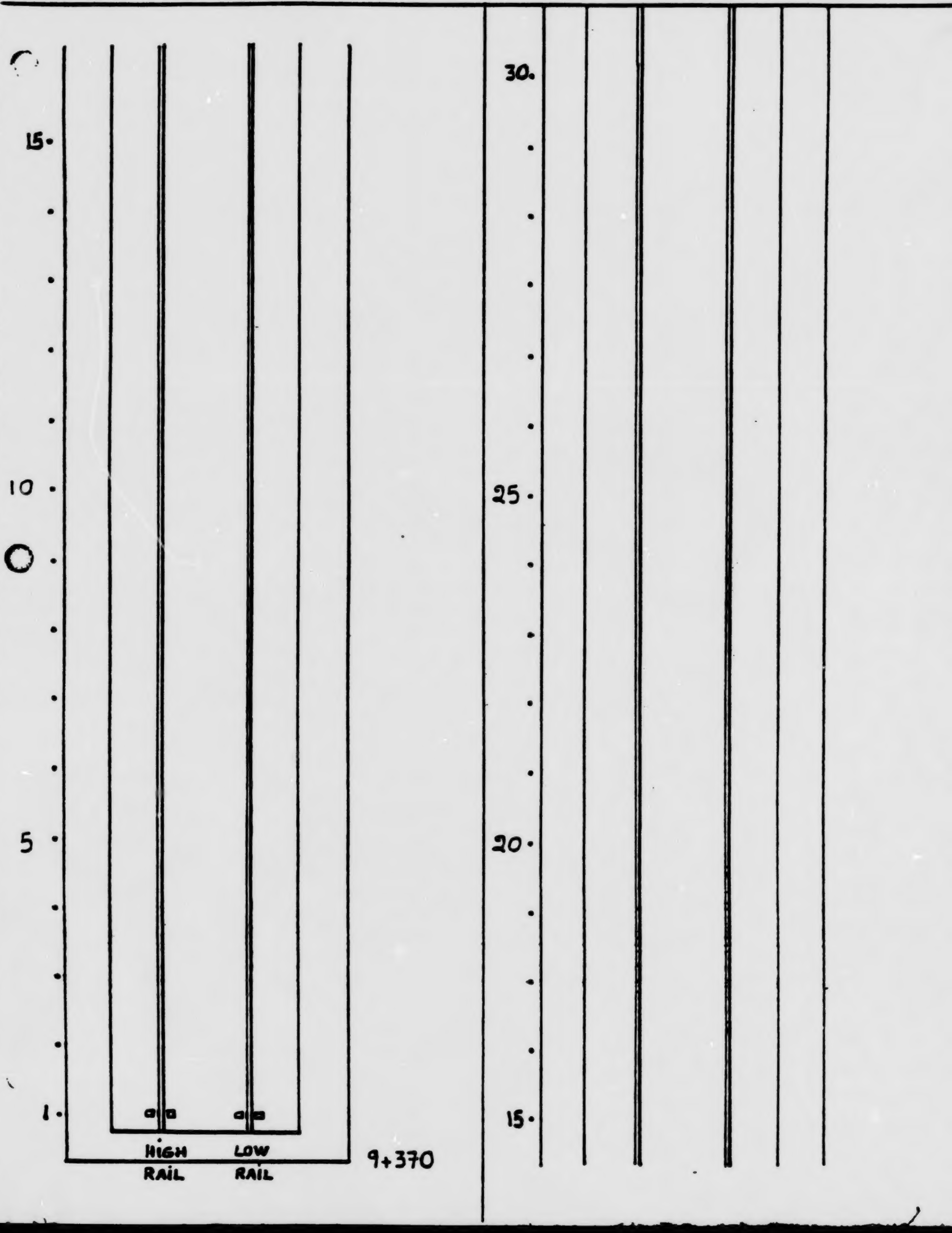
Some work has been done to facilitate water drainage from the subgrade. This was done in an effort to reduce pumping action of the PACT.

It is planned to conduct the last inspection in September 1986 which will mark two years of operation of the PACT.

APPENDIX A

CRACK SURVEY

PACT SLAB - ALBERT CANYON - CRACK SURVEY - (MAY 1986) 7A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HIGH RAIL
LOW RAIL
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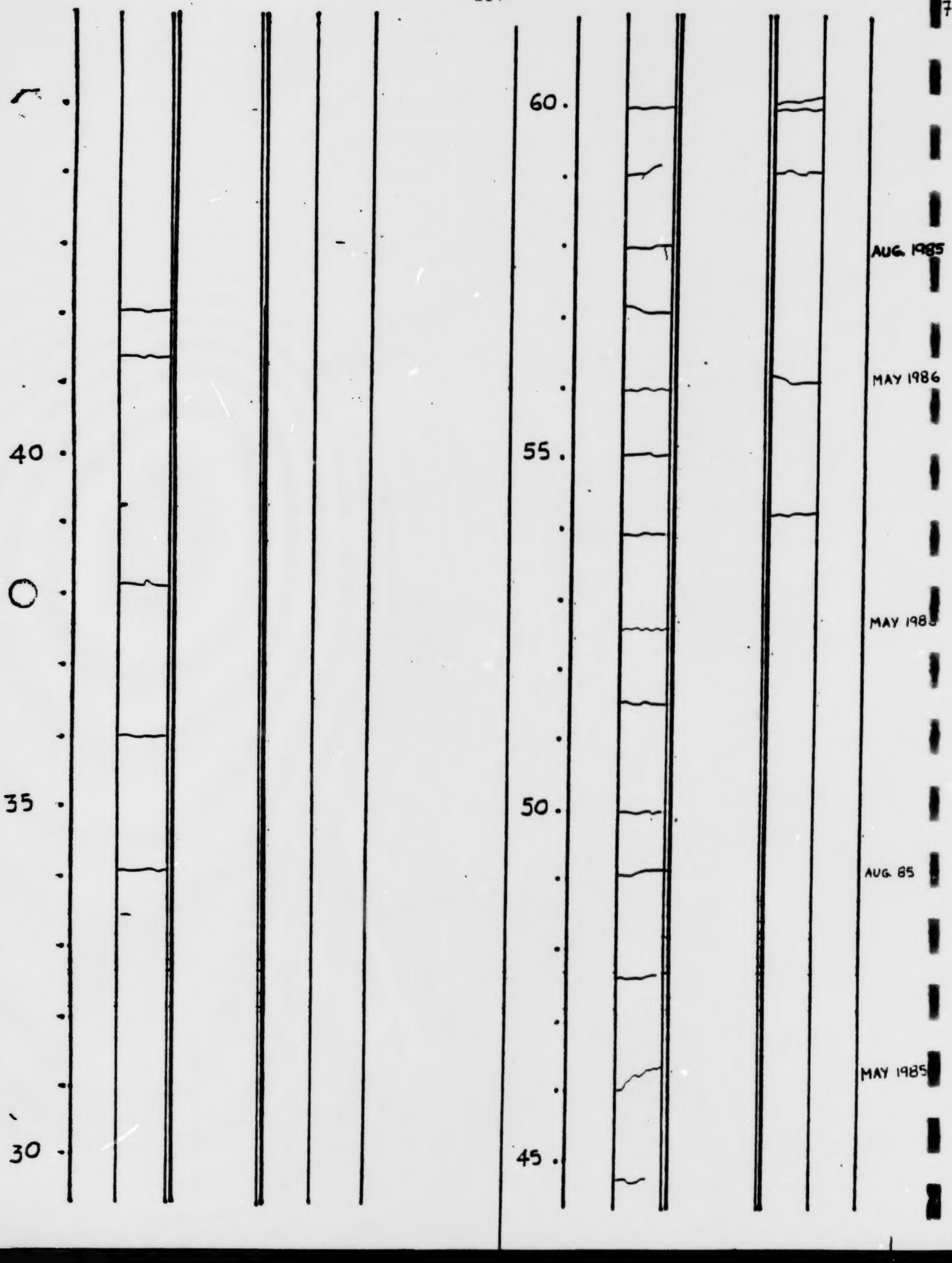
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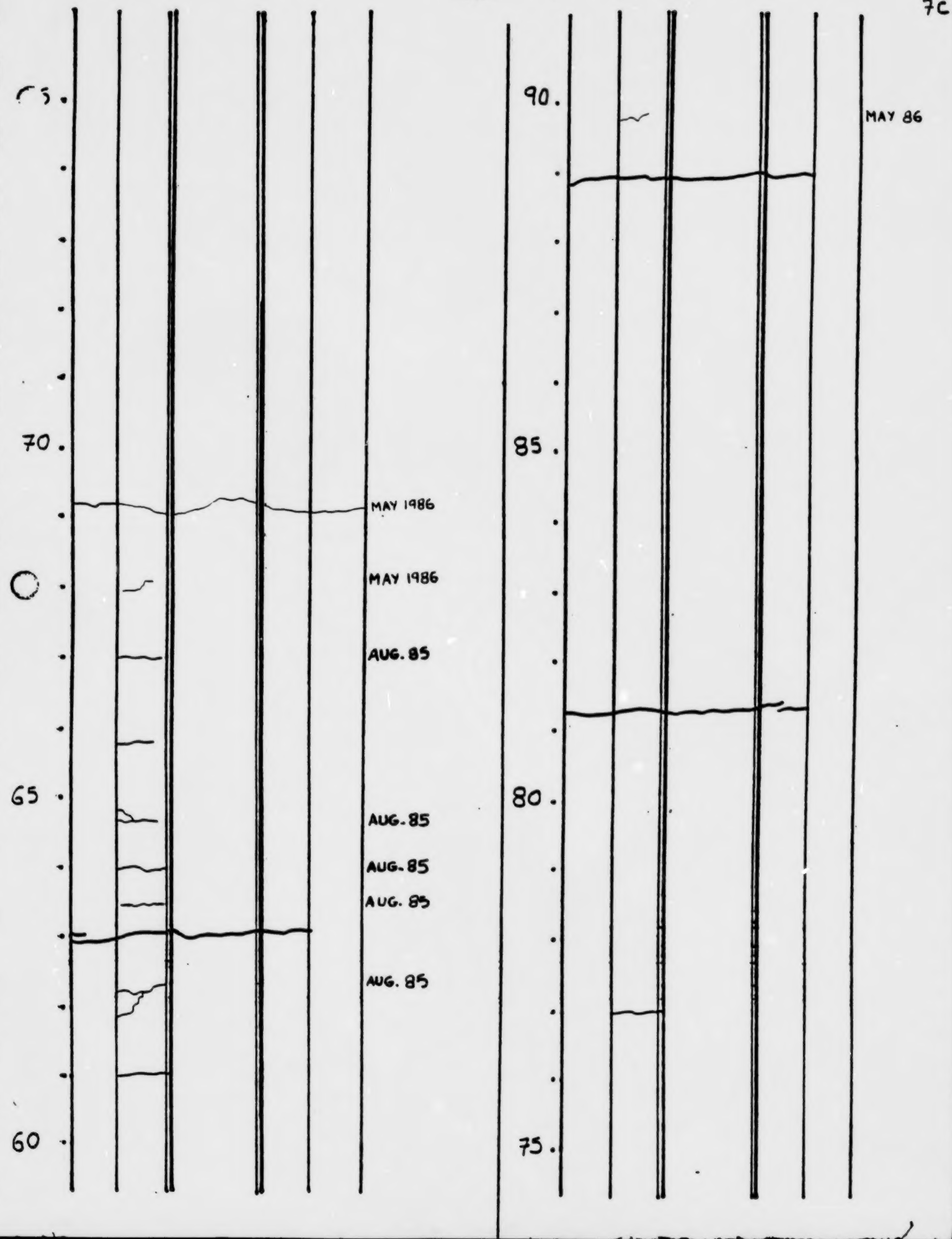
MAY 198
AUG. 85
MAY 1985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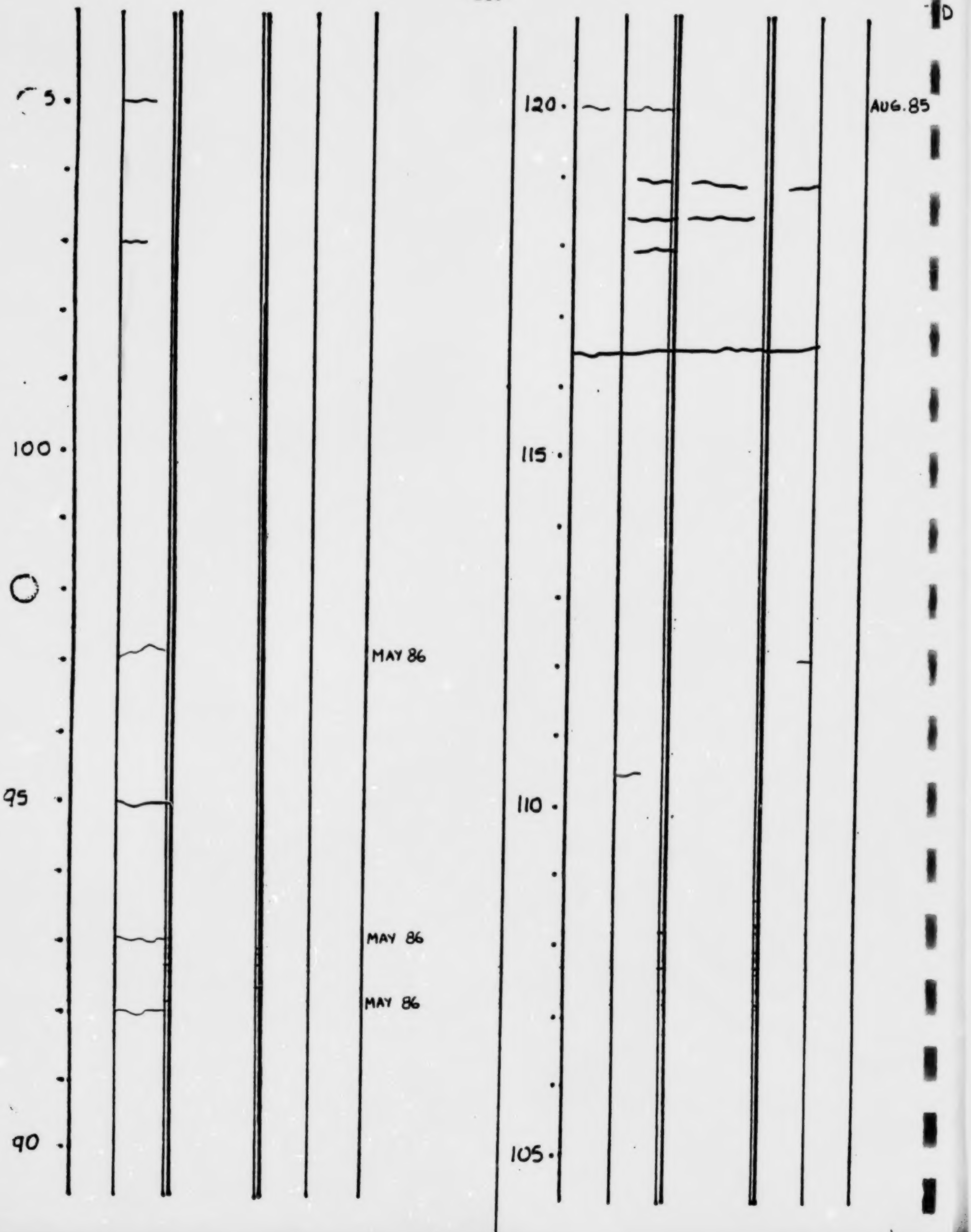
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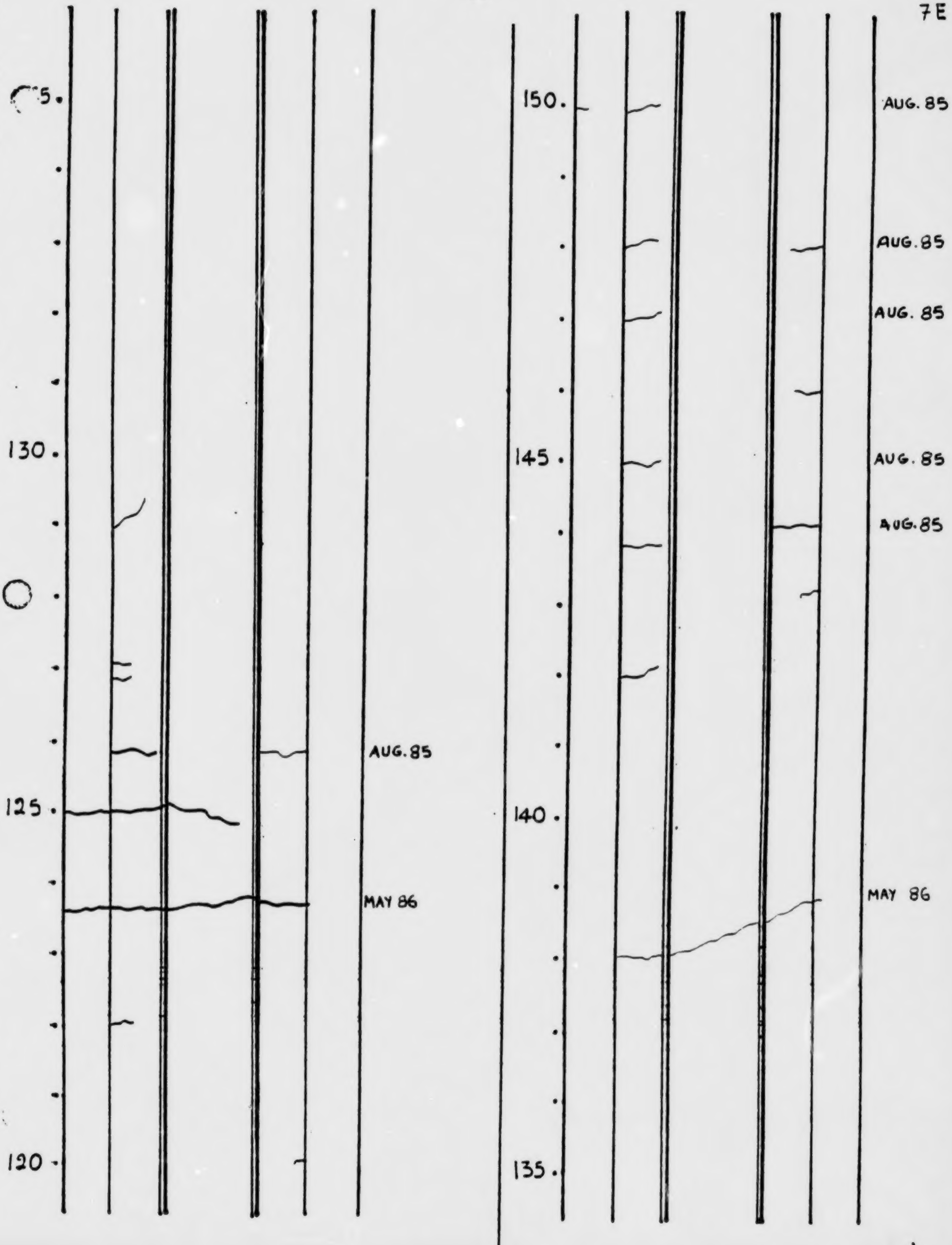
7E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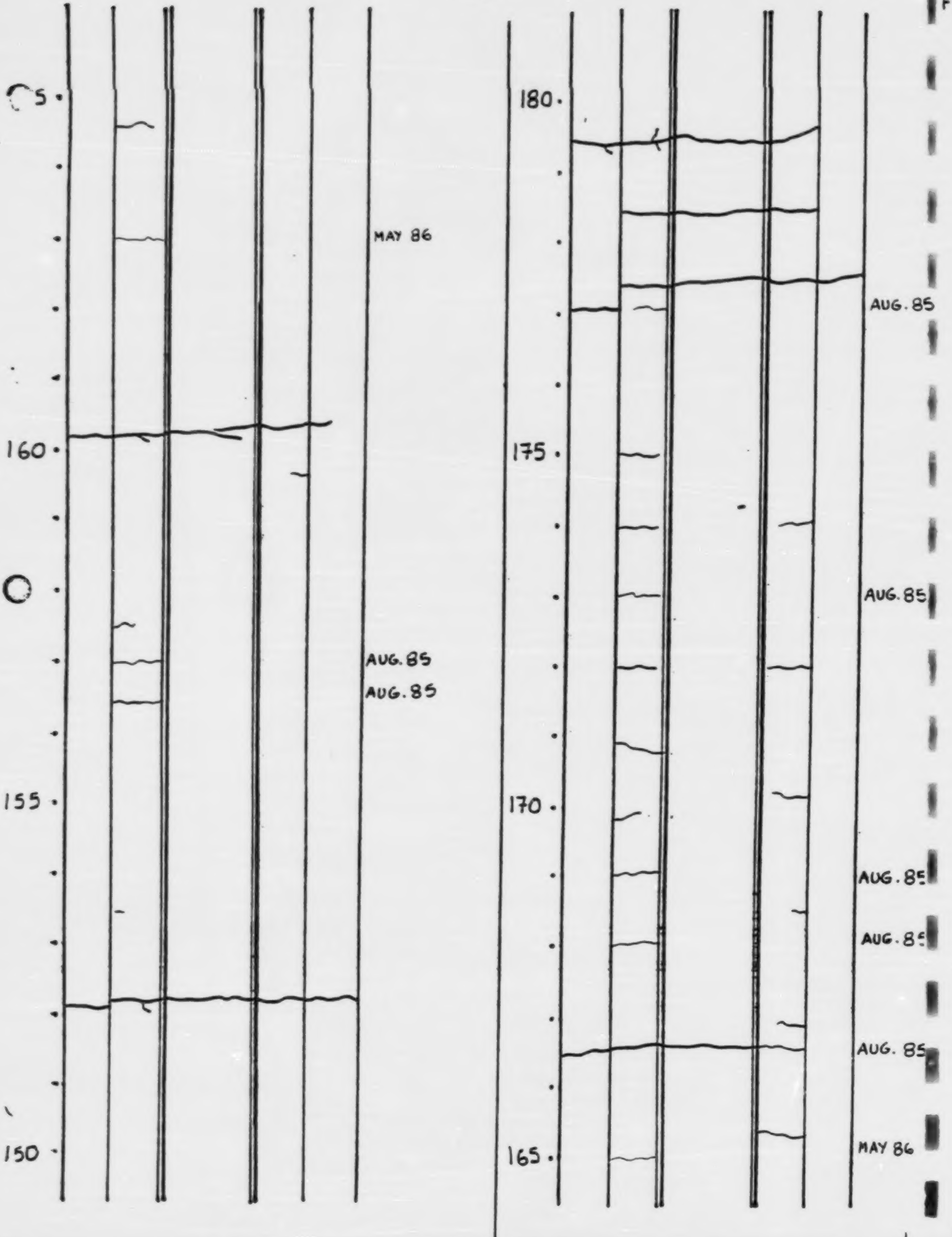
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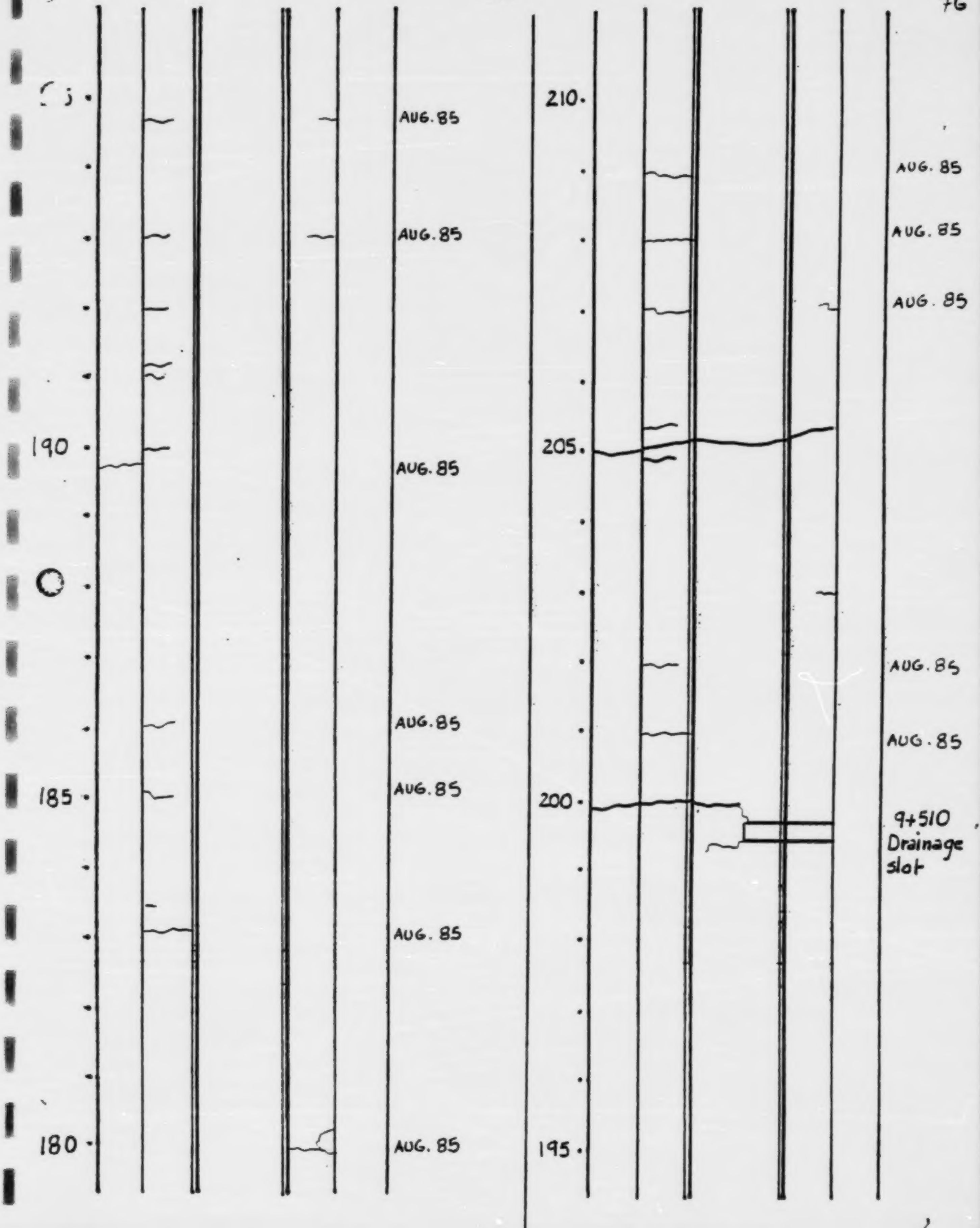
MAY 86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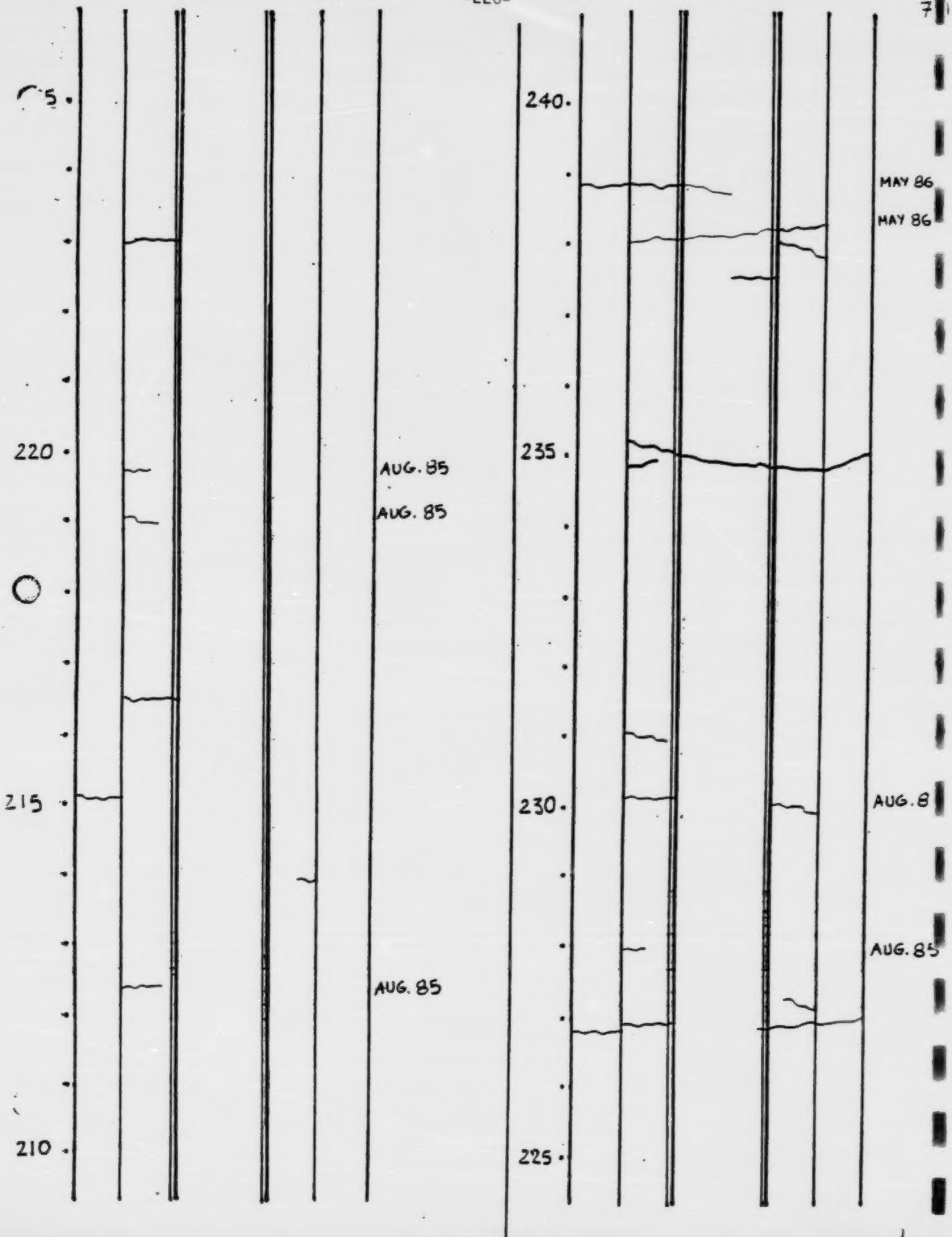
AUG. 85
200
9+510
Drainage
slot
195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MAY 86
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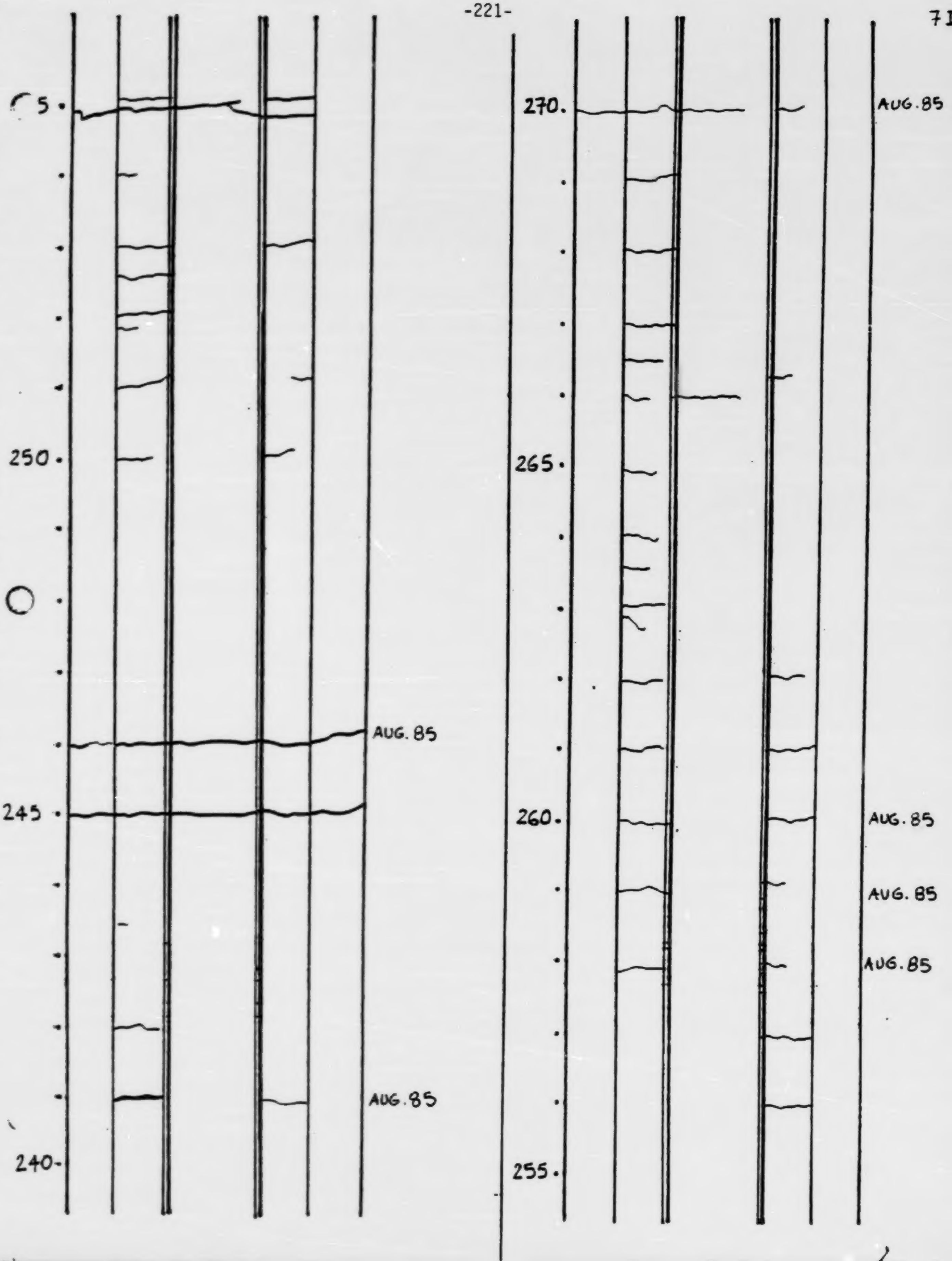
AUG. 85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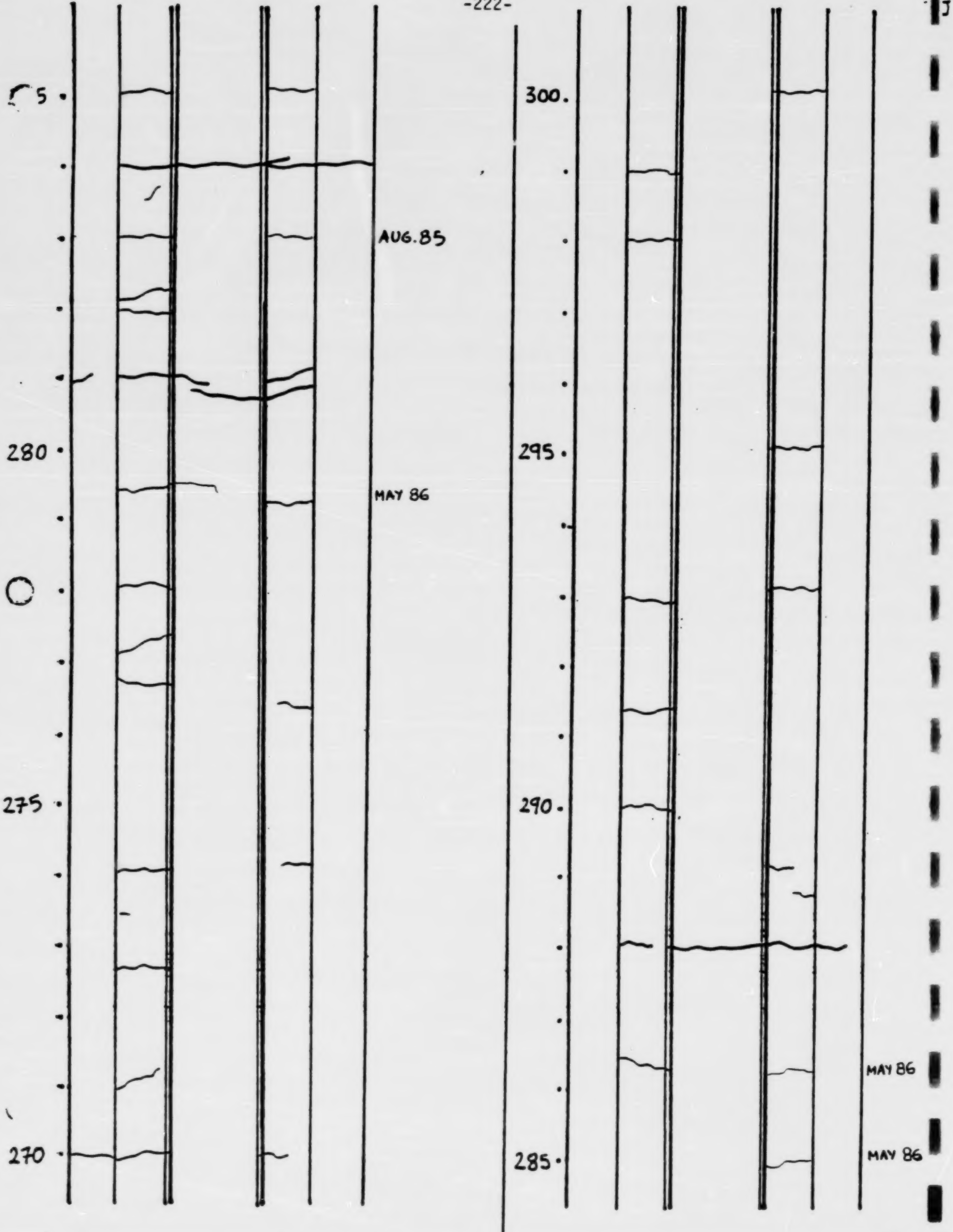
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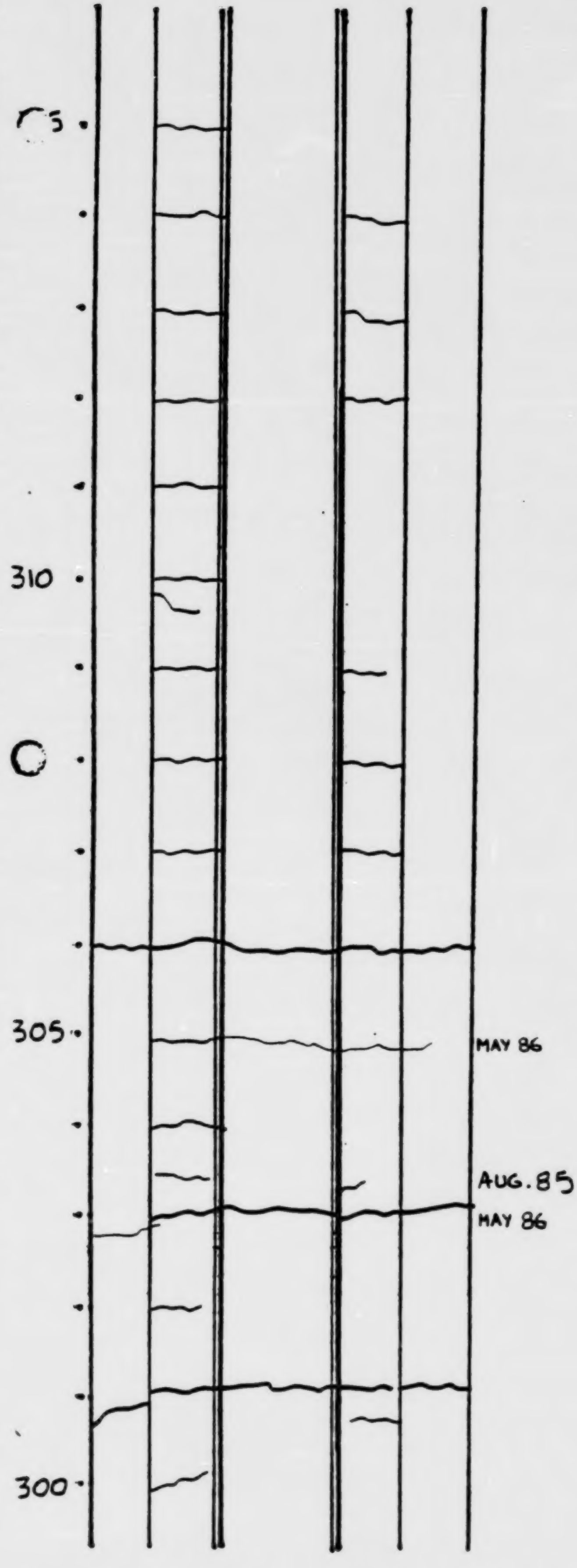
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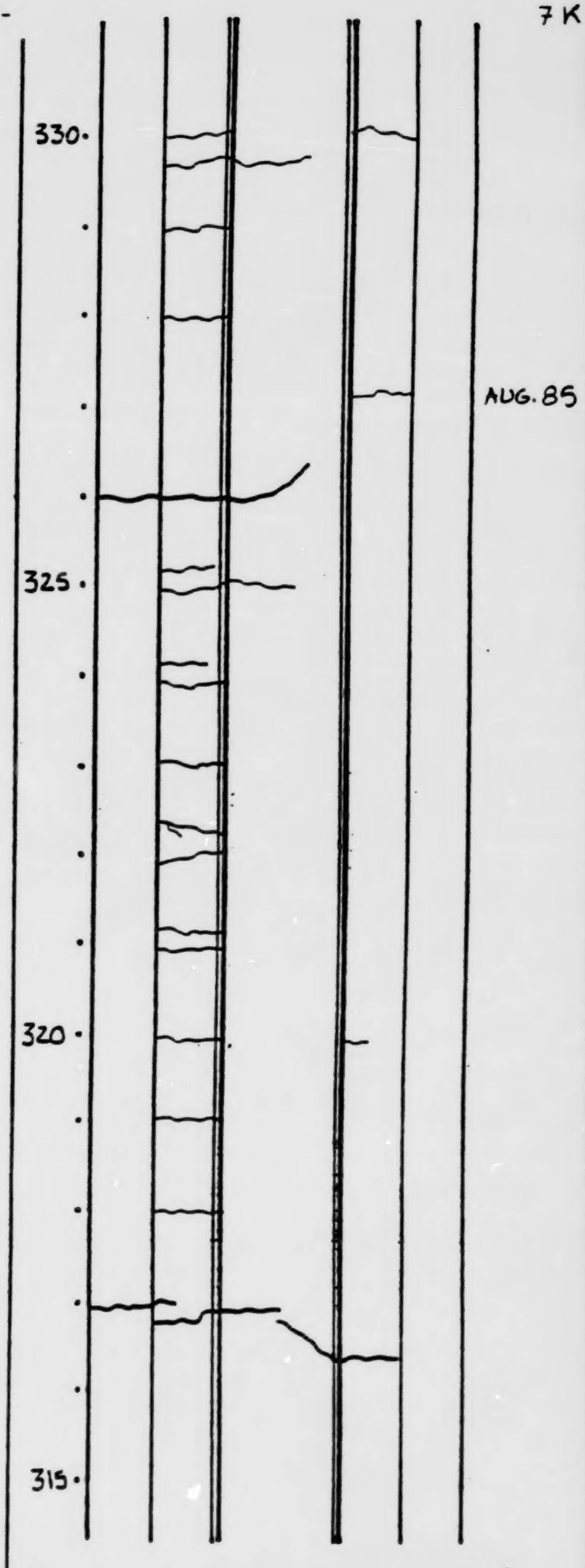
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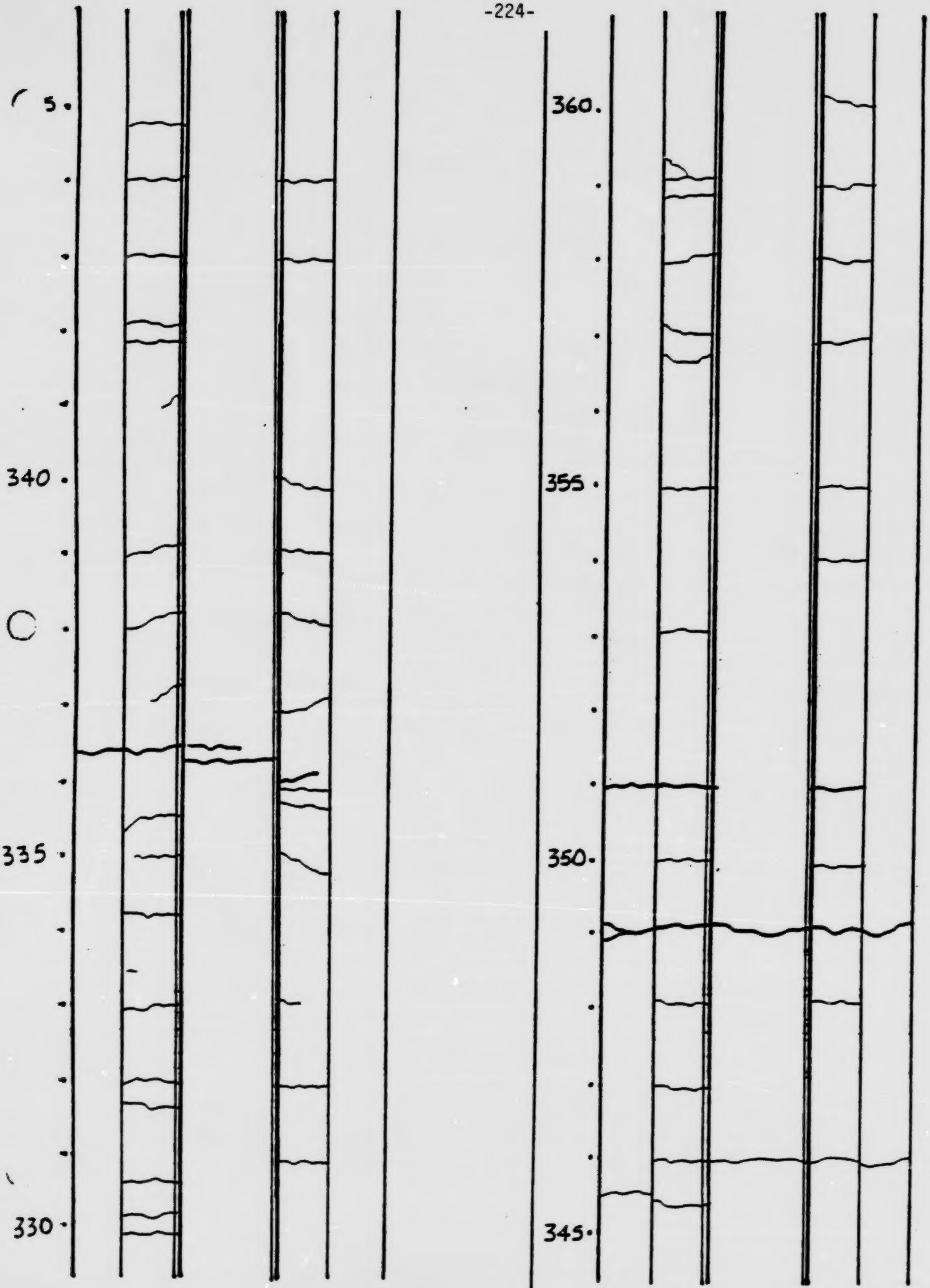
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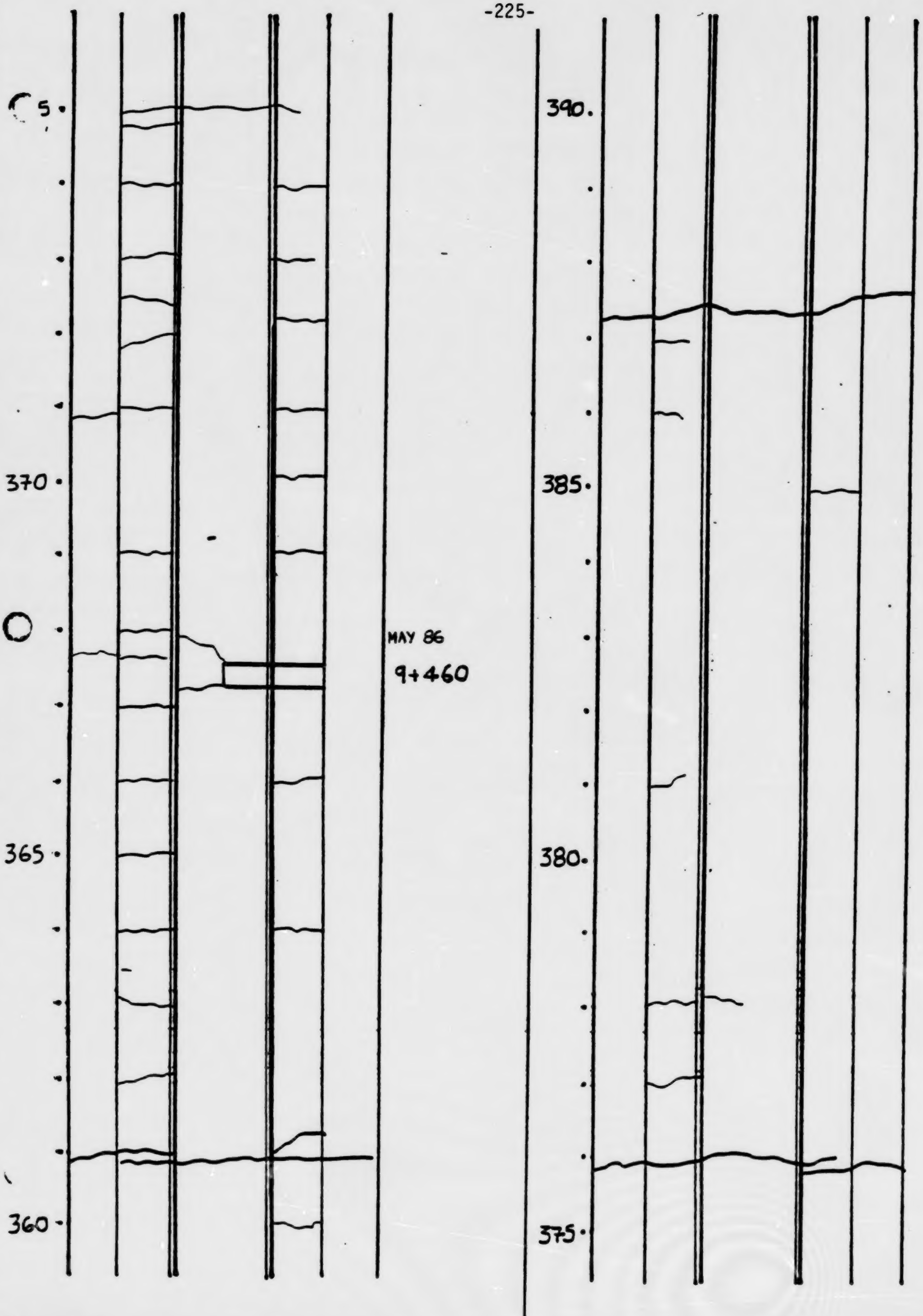
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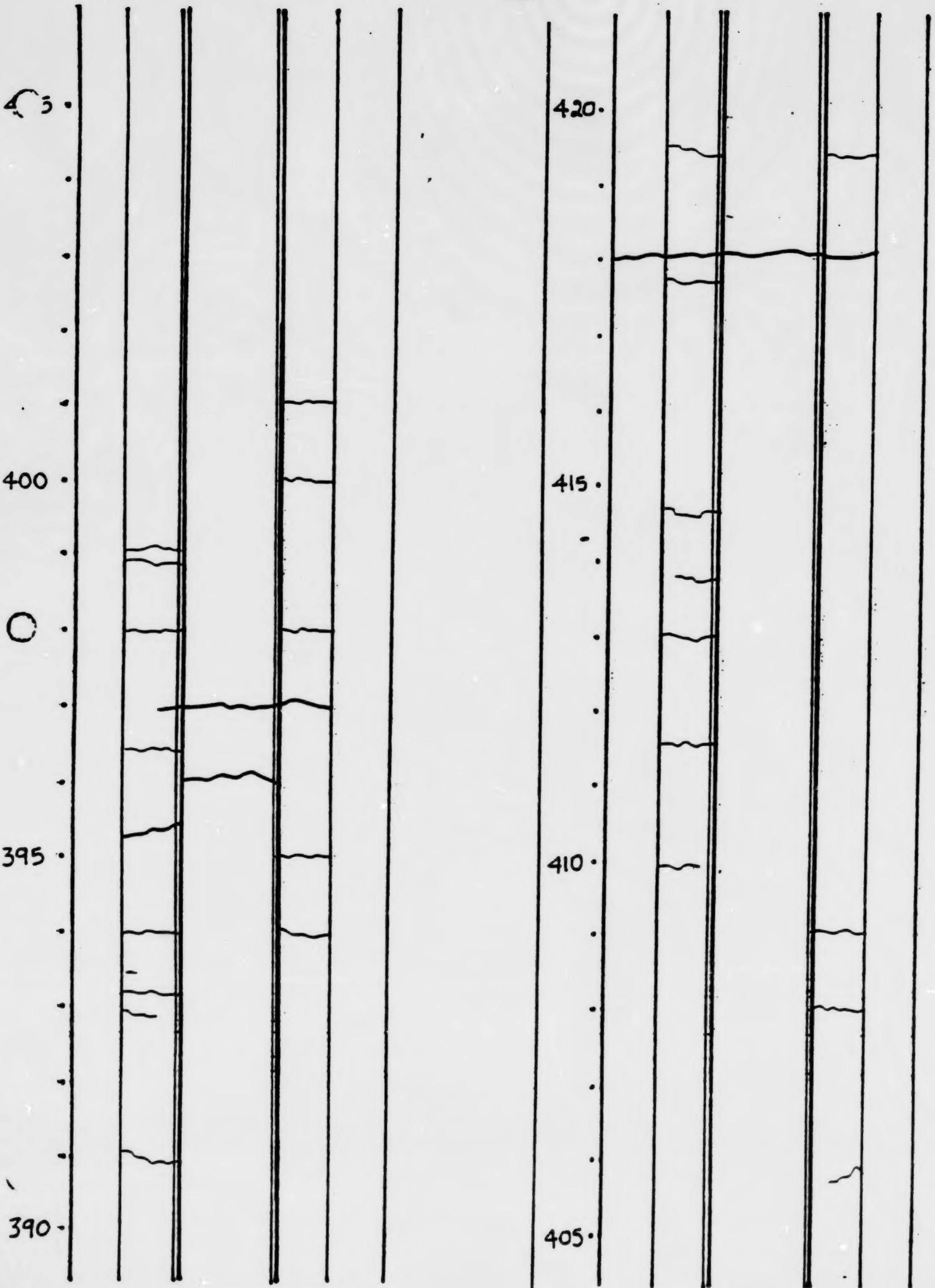

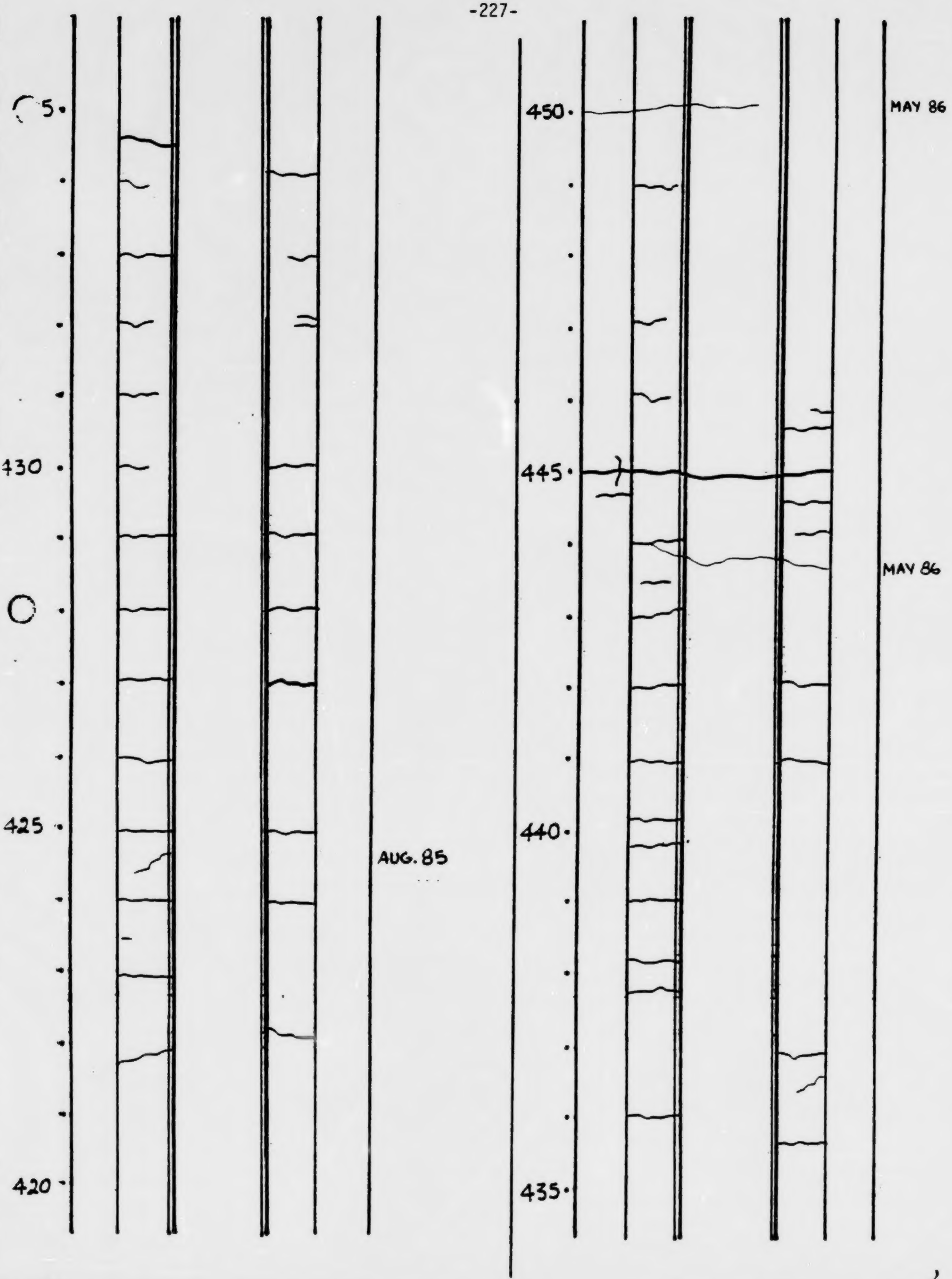
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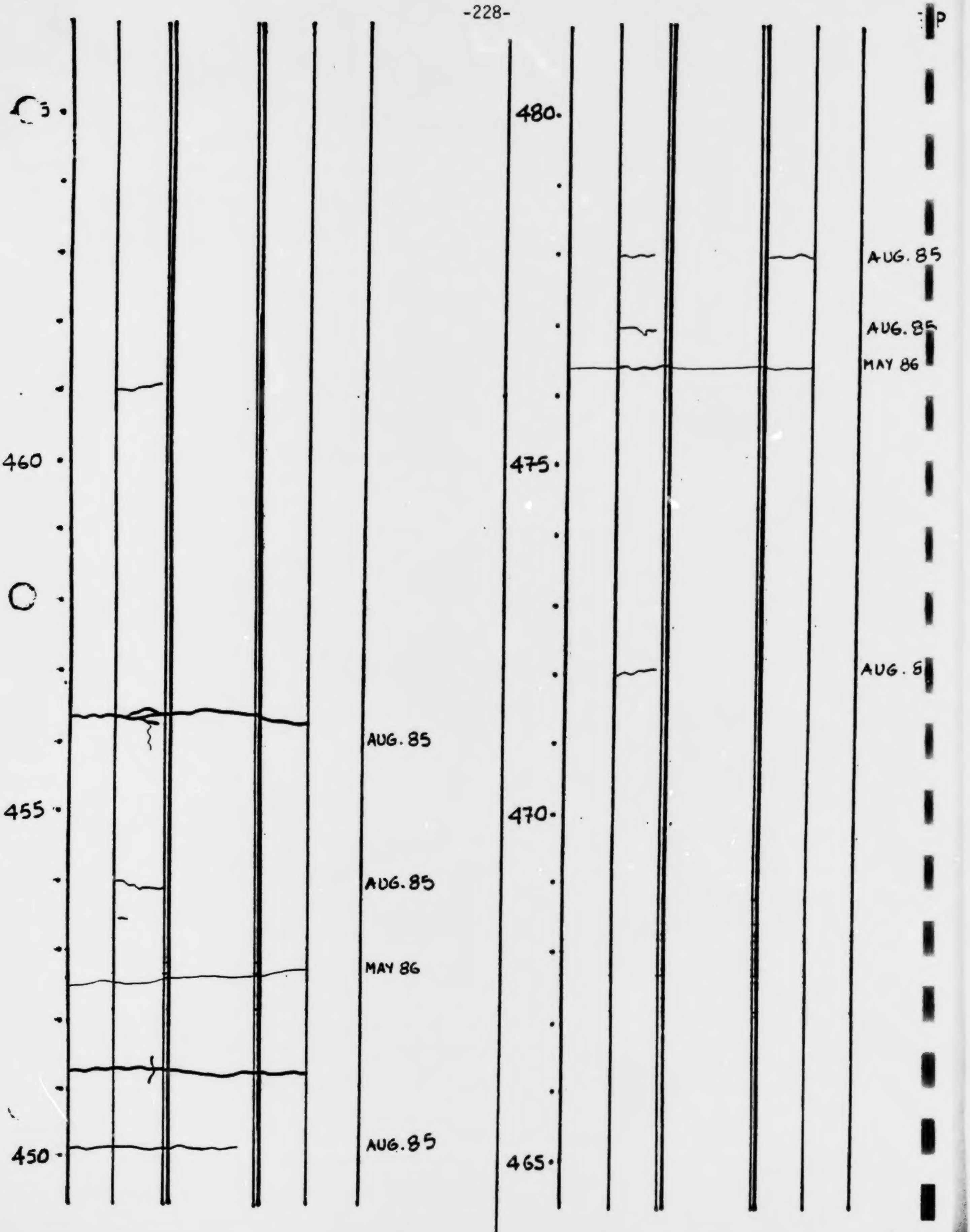
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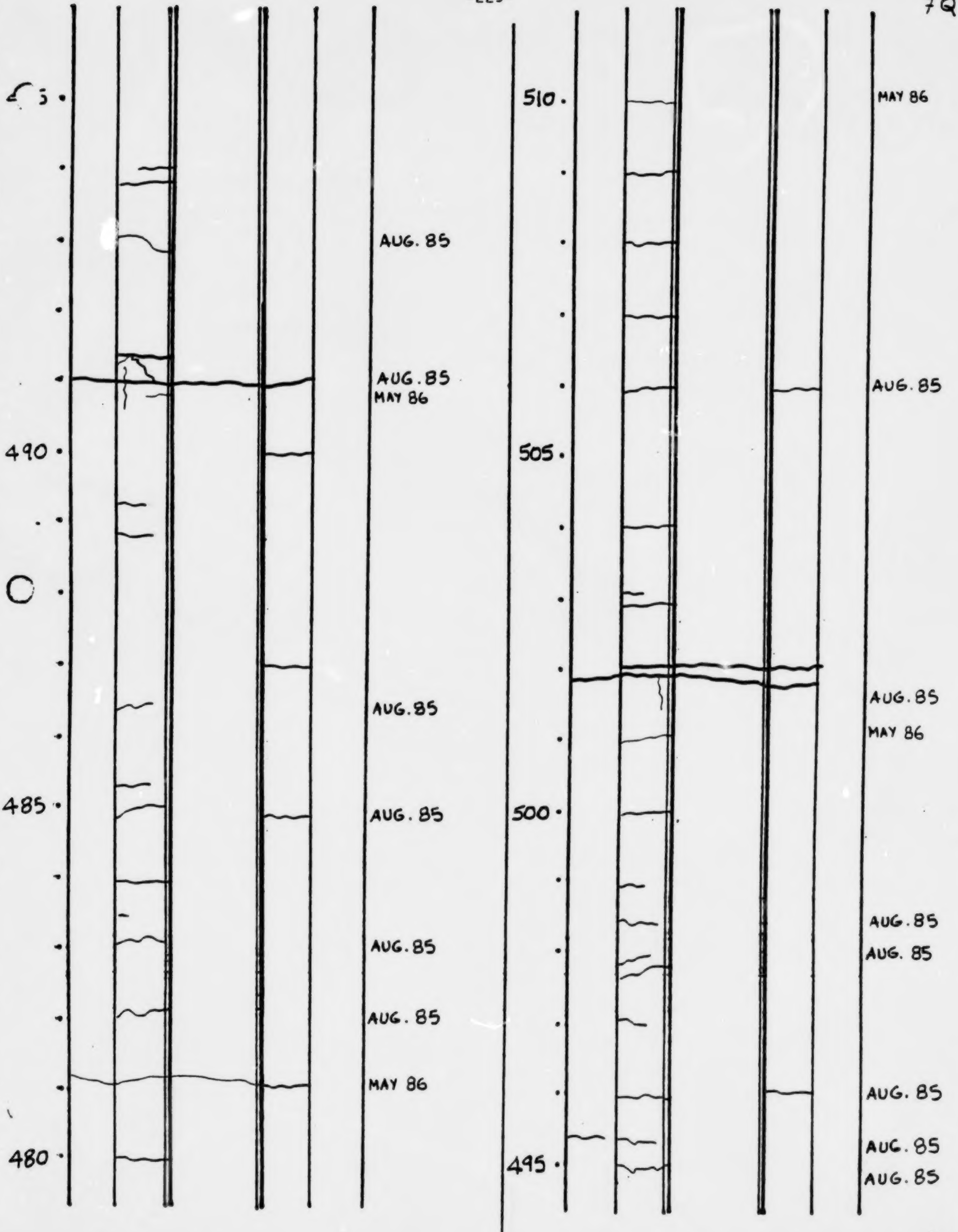
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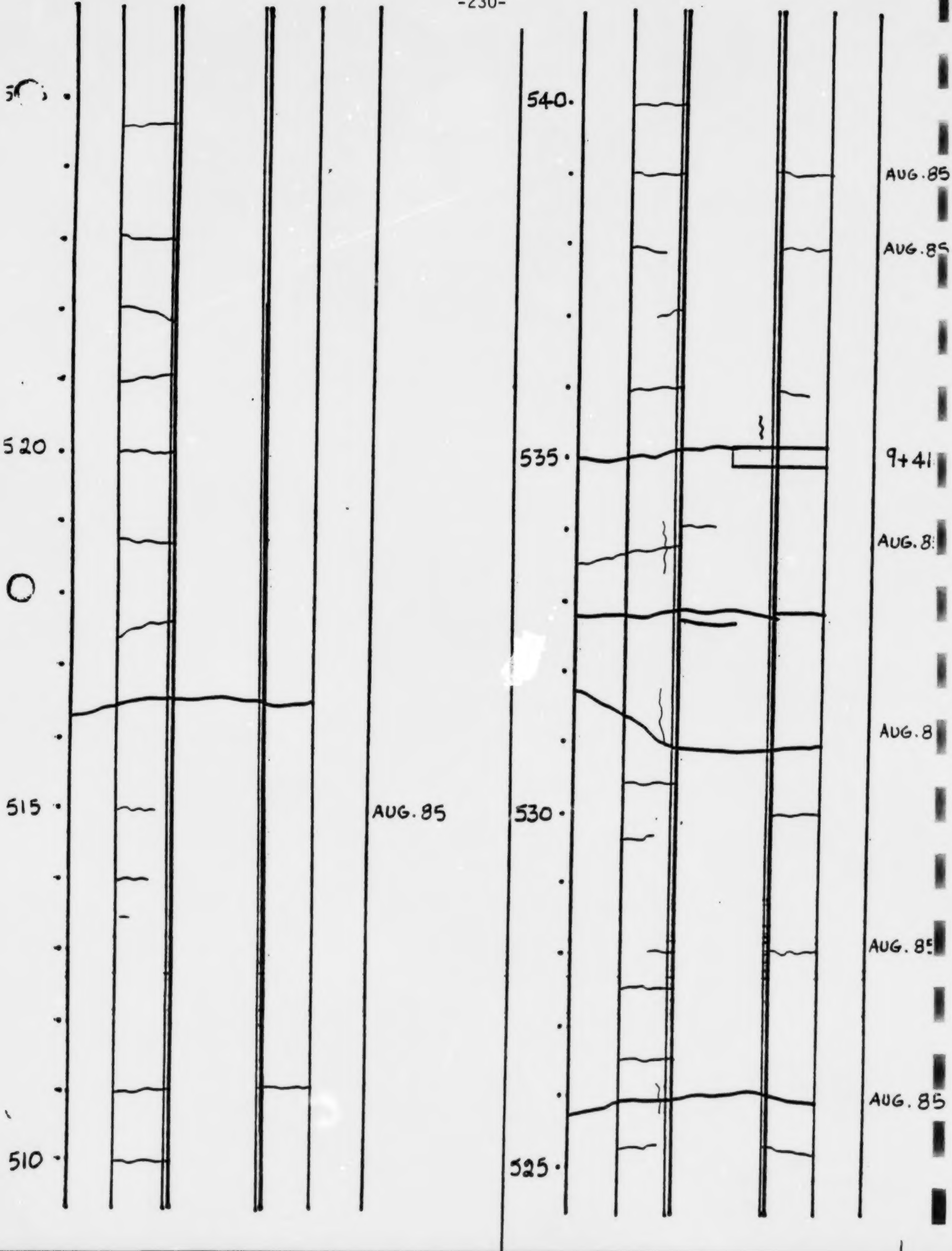

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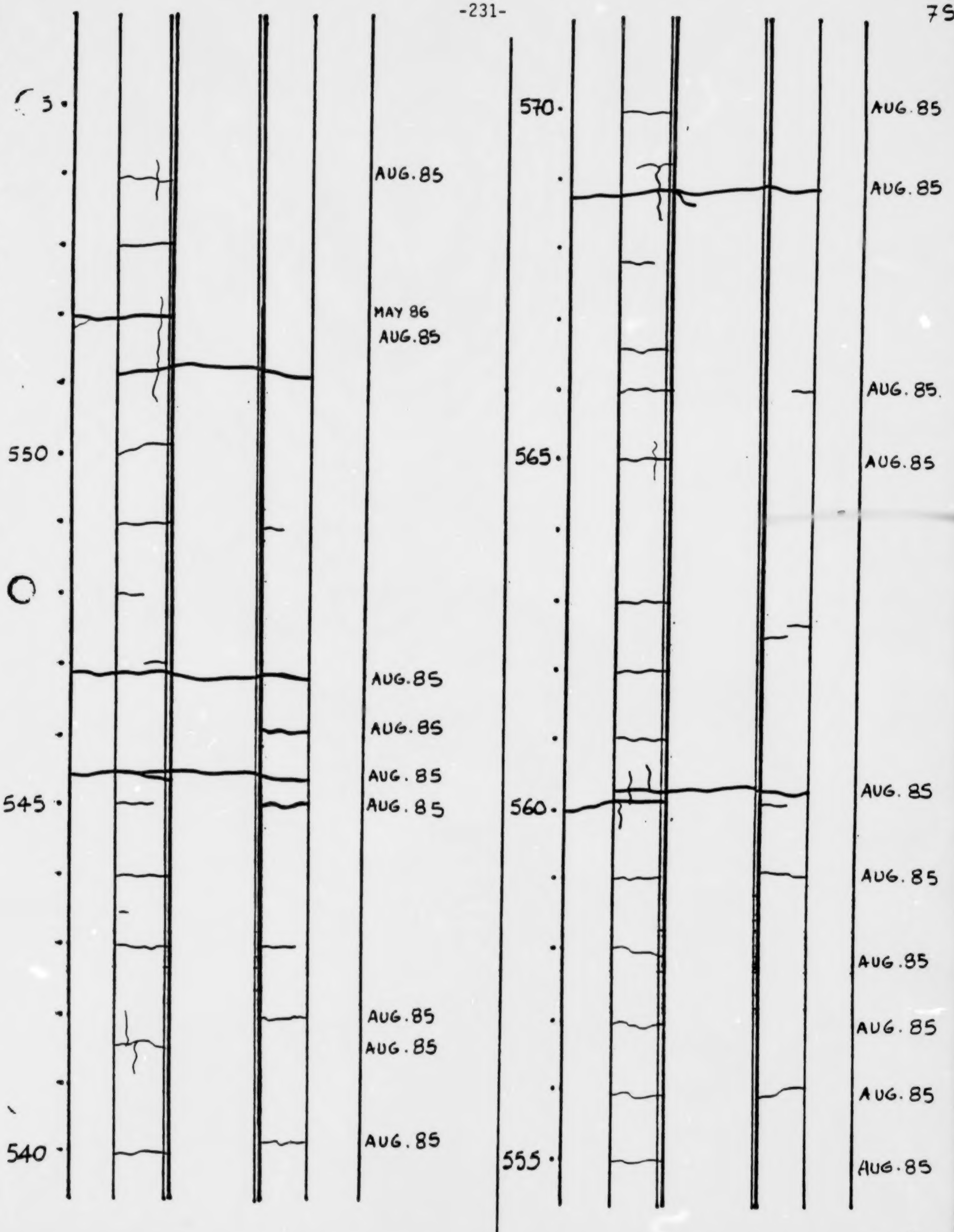
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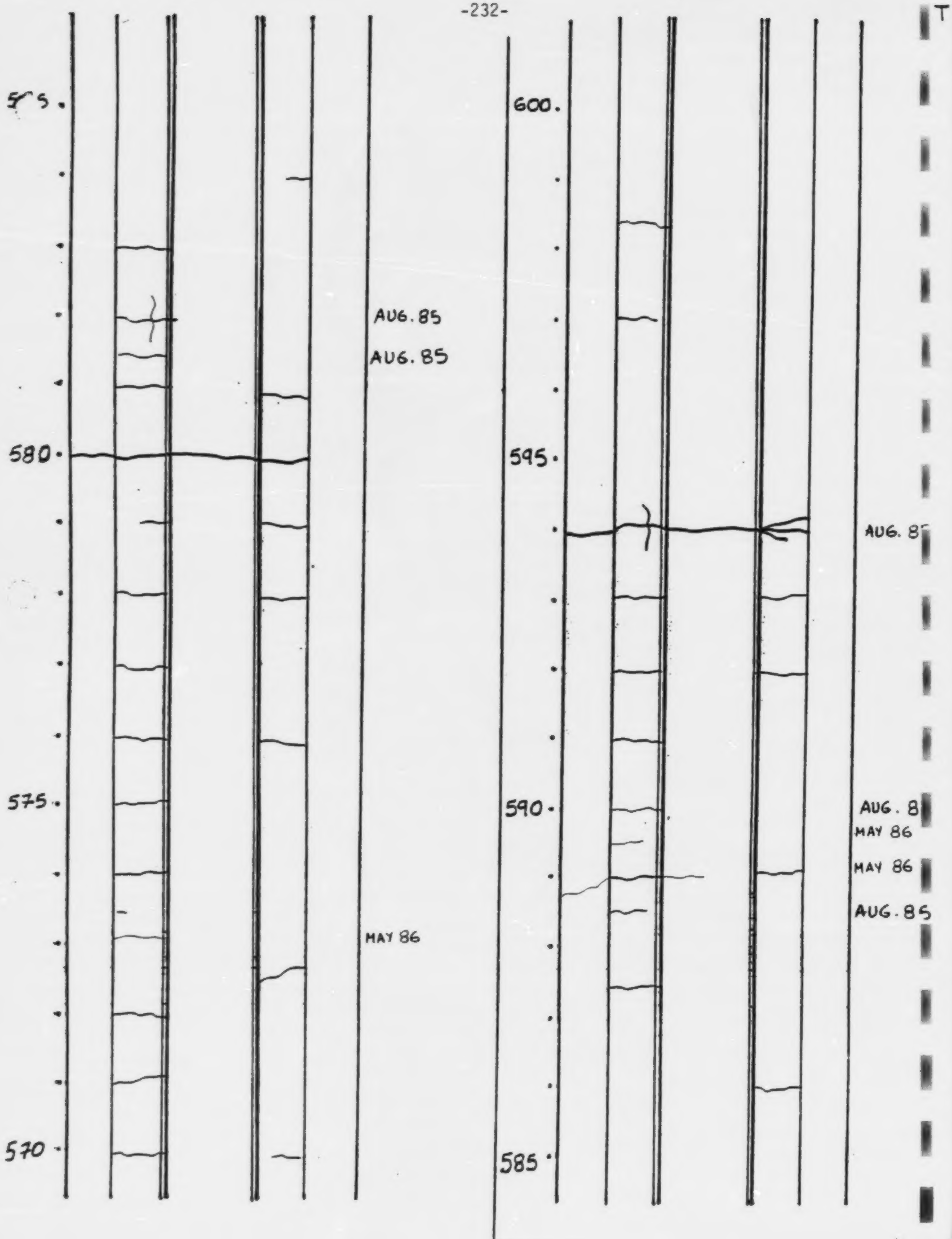
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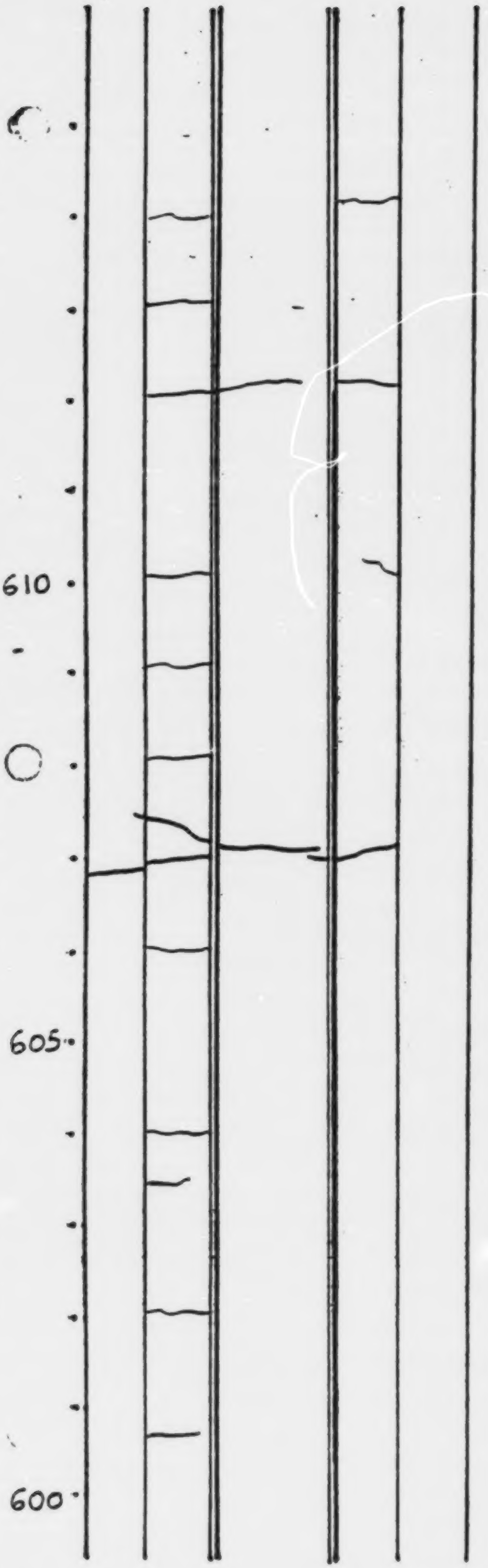

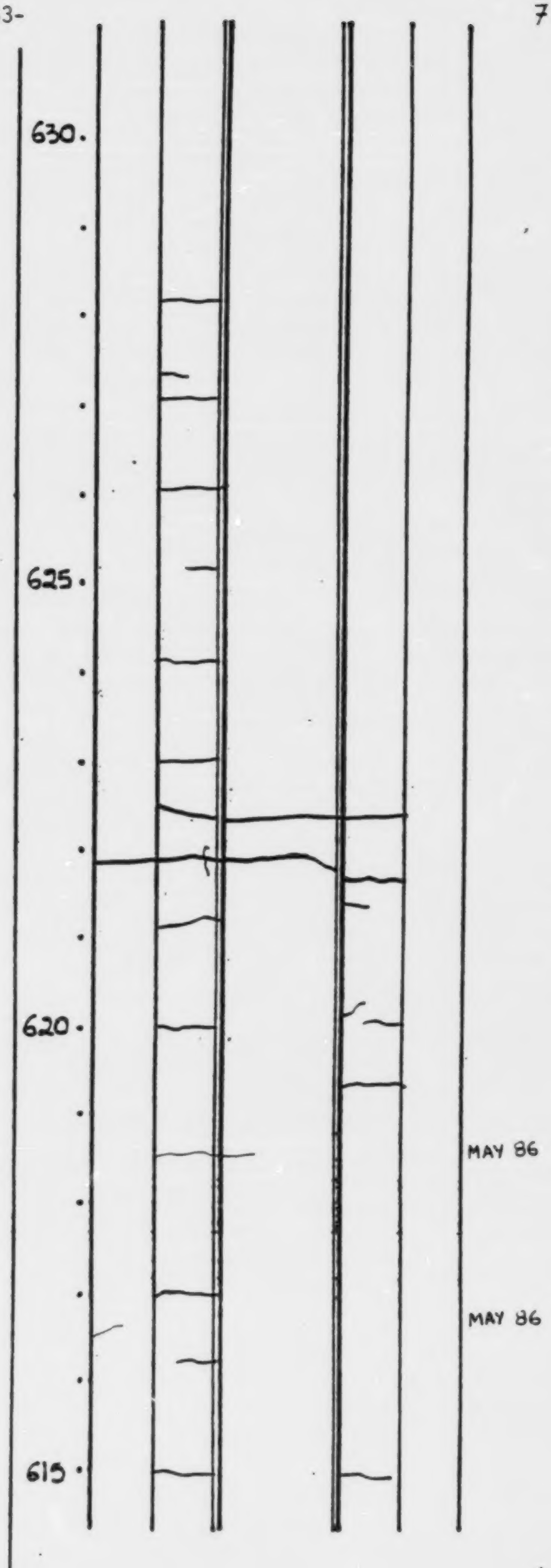
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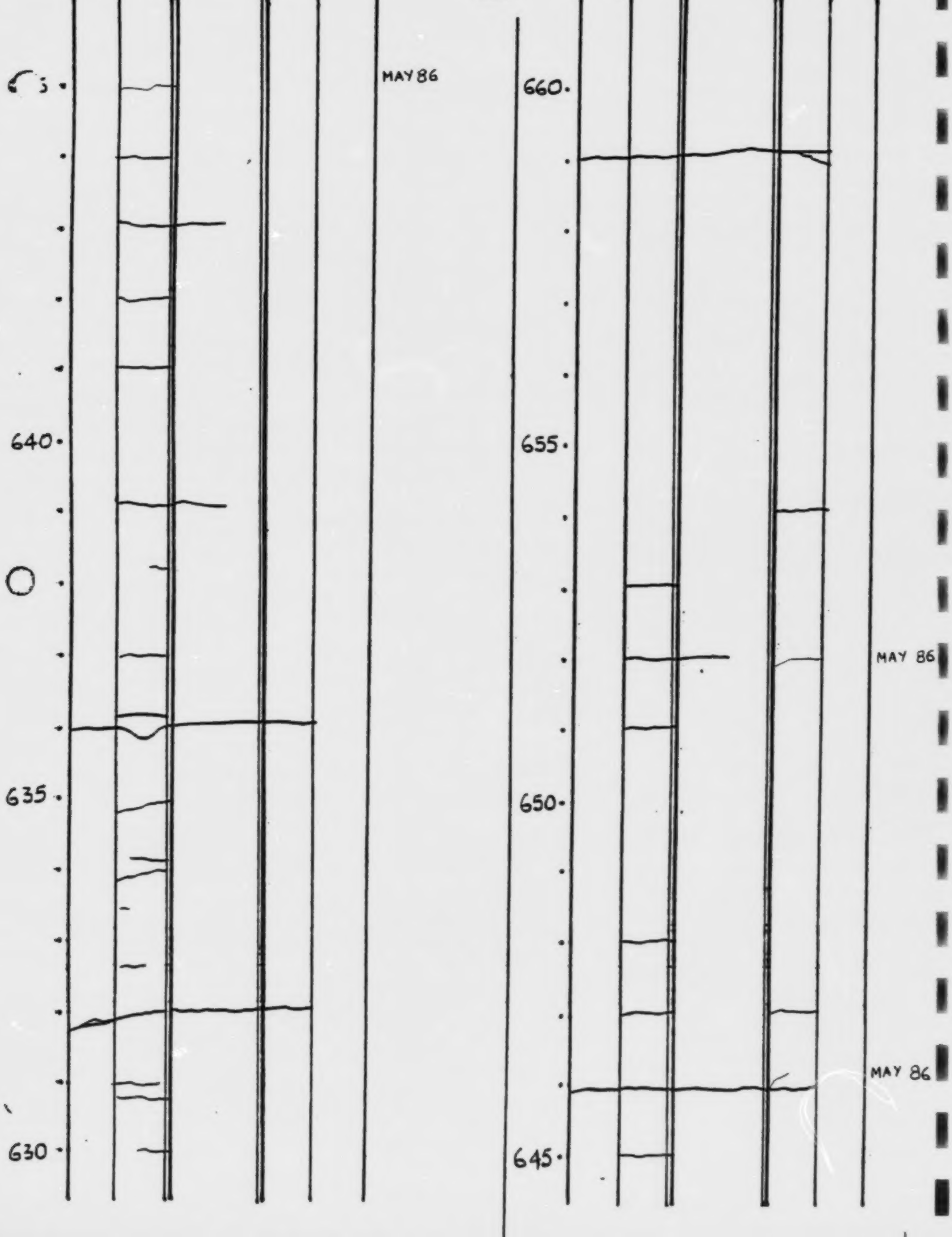
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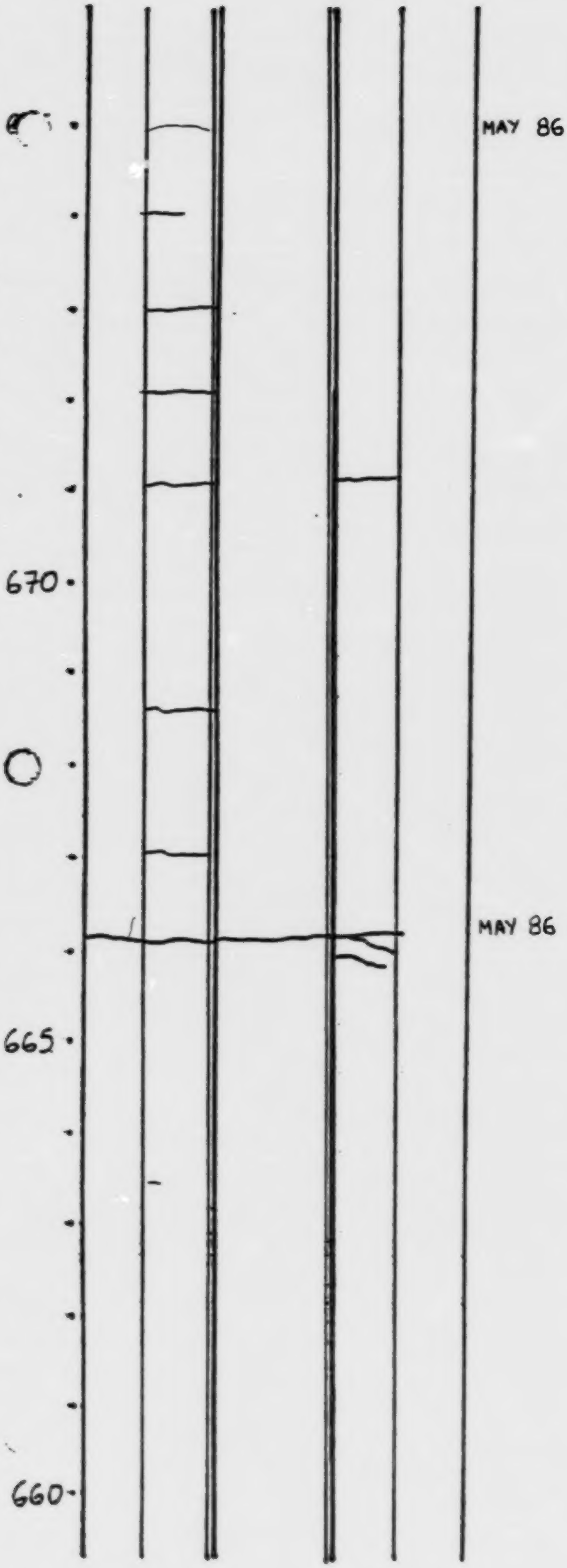
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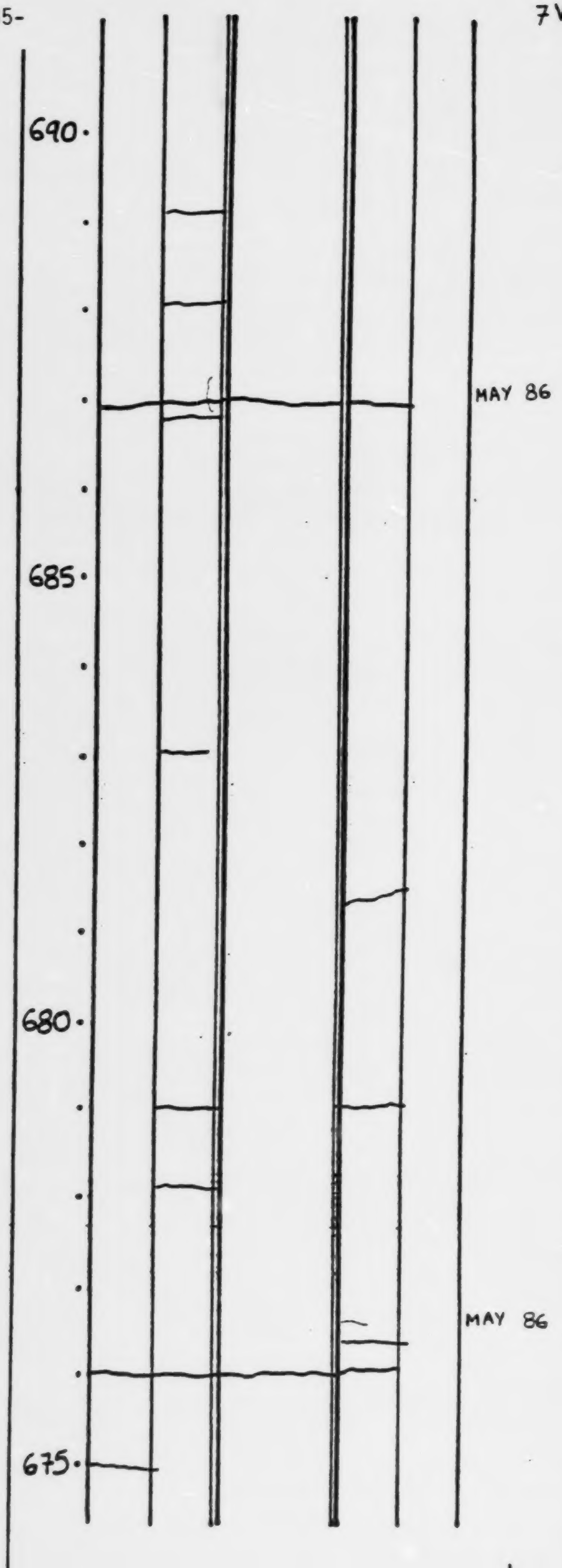
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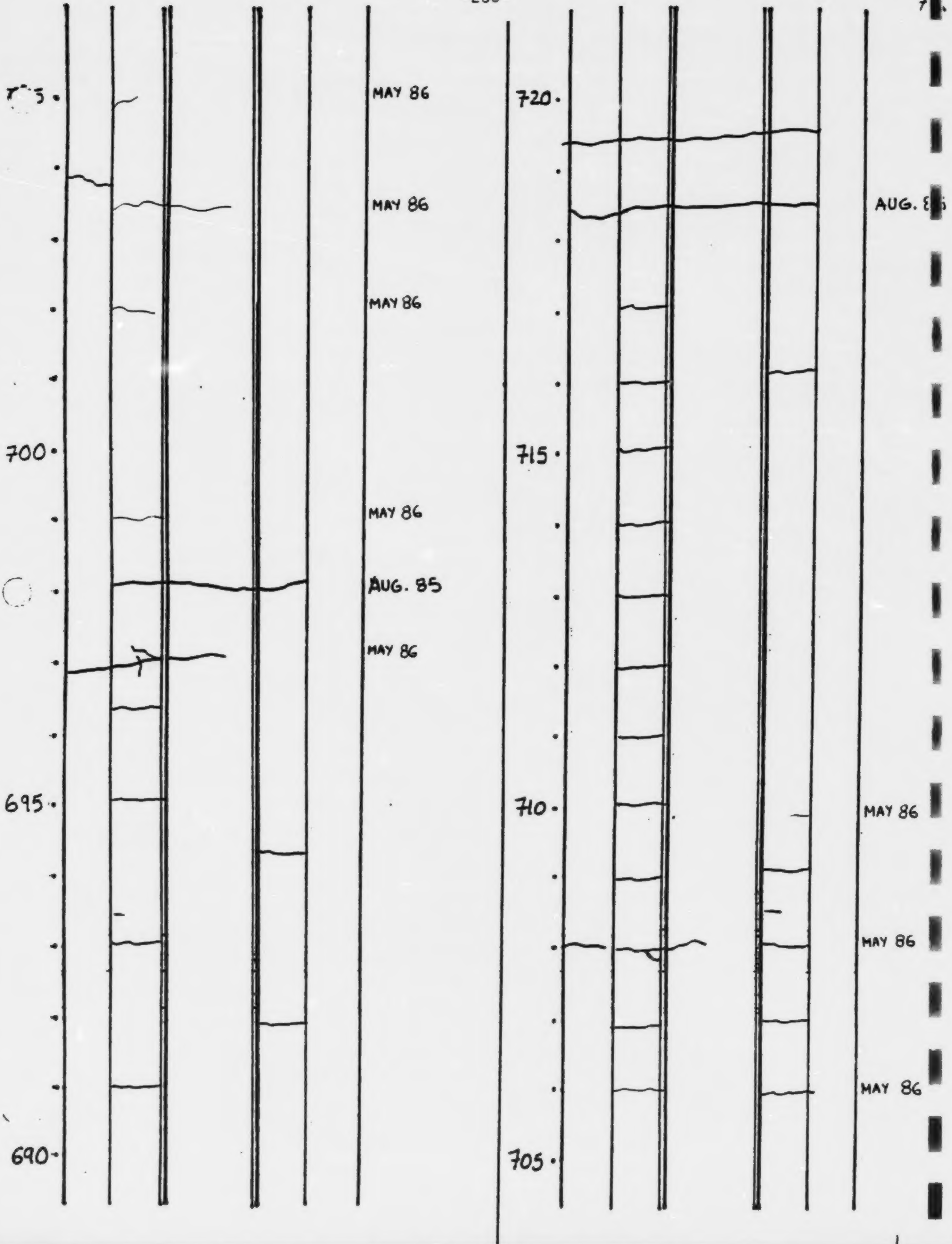
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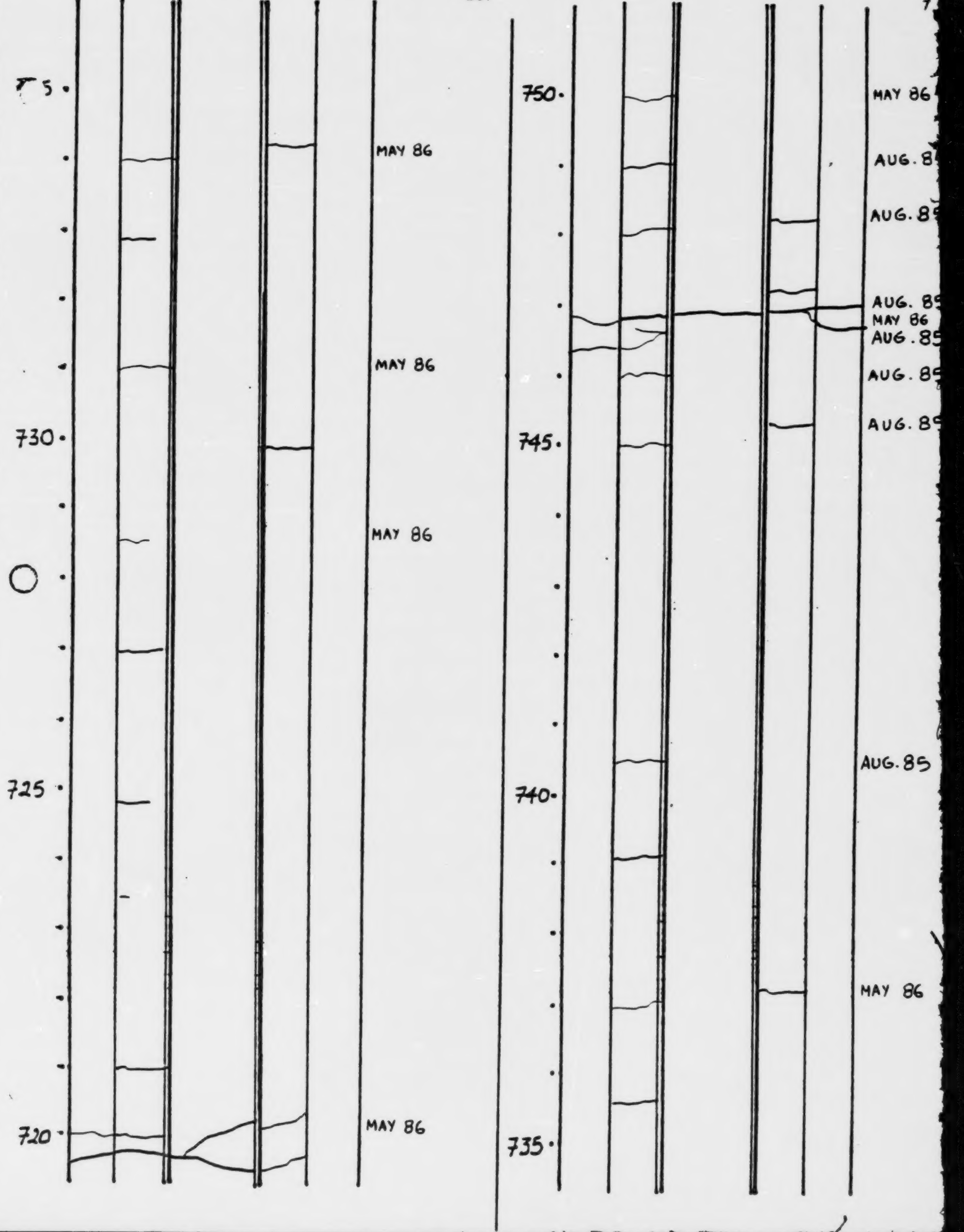
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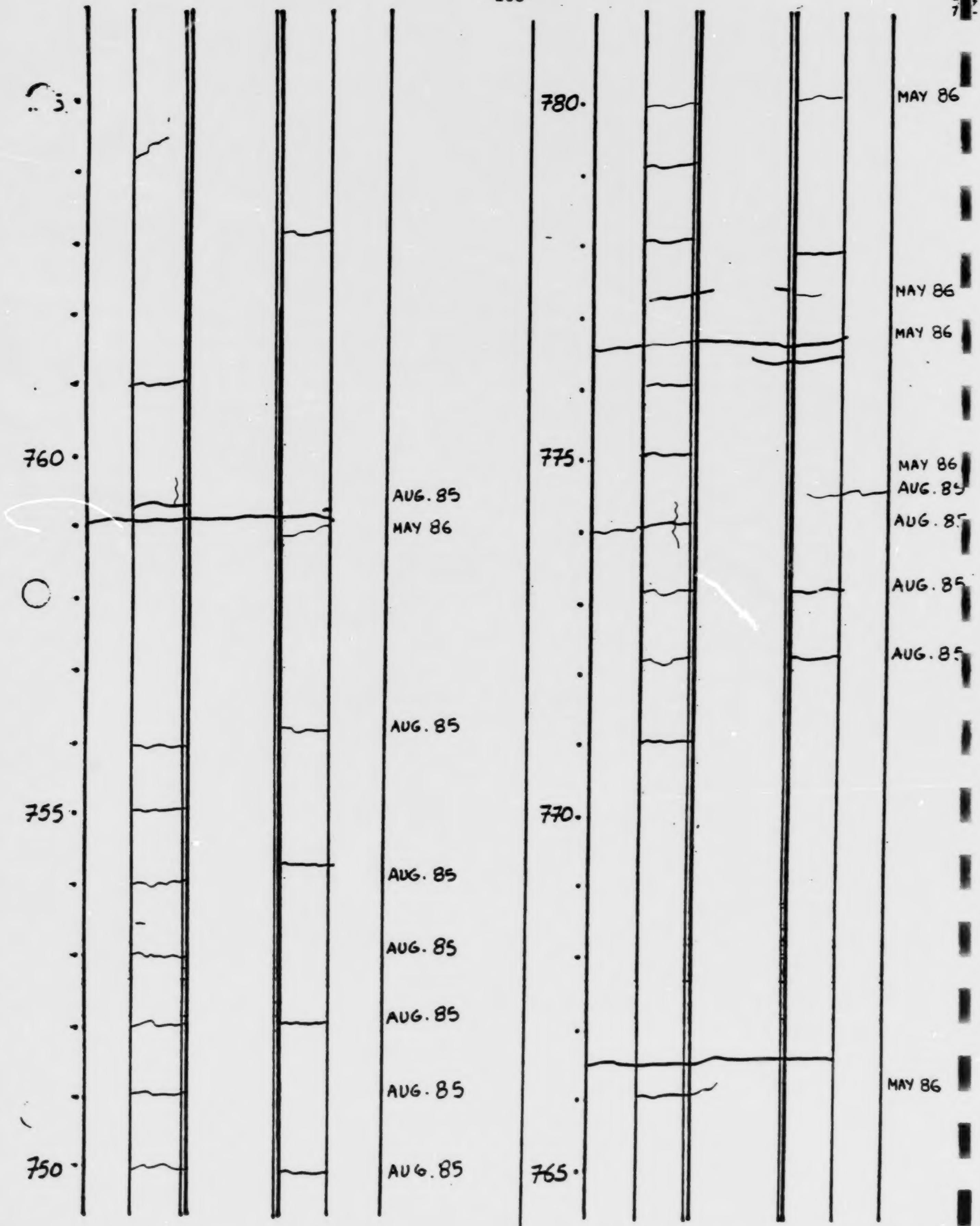
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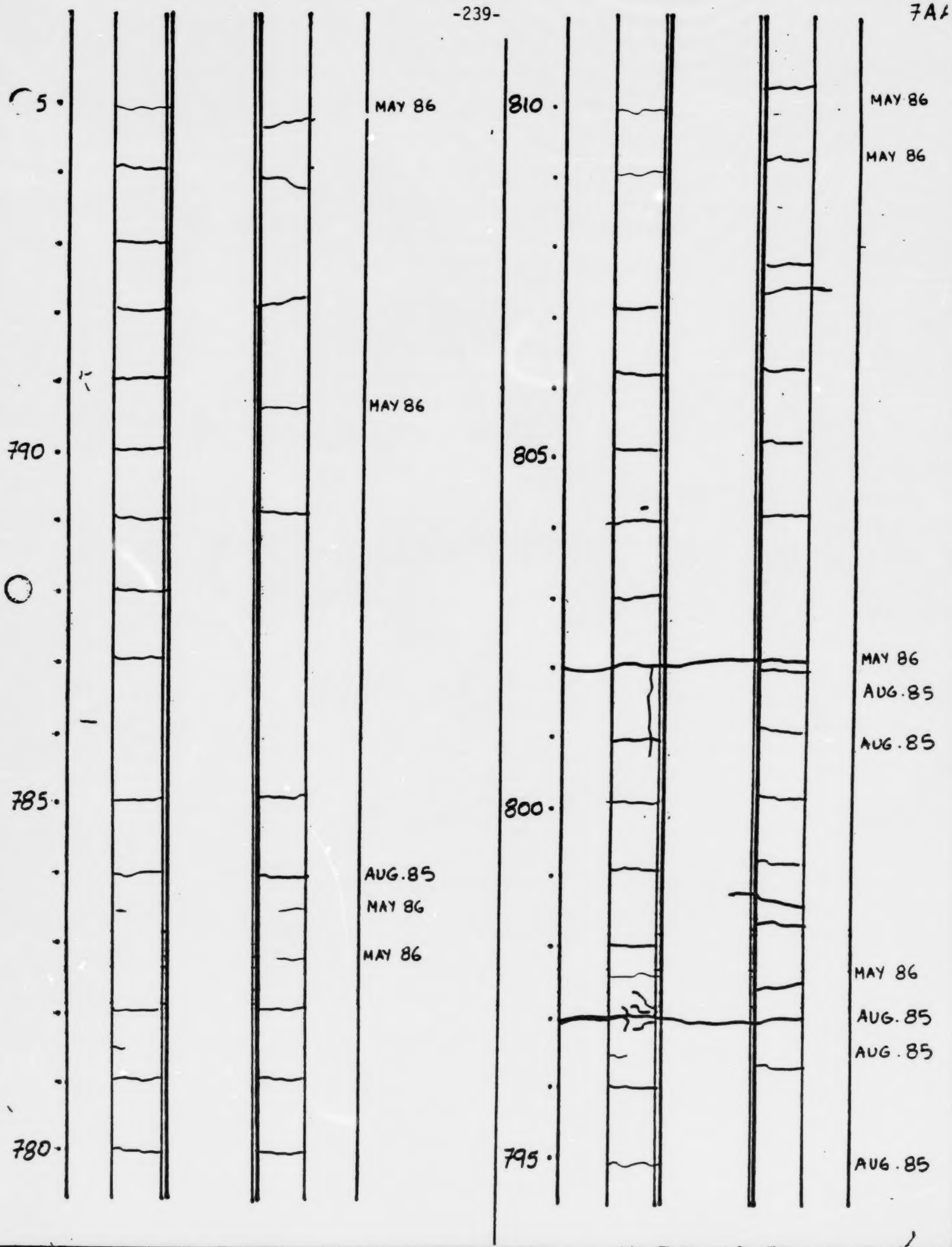
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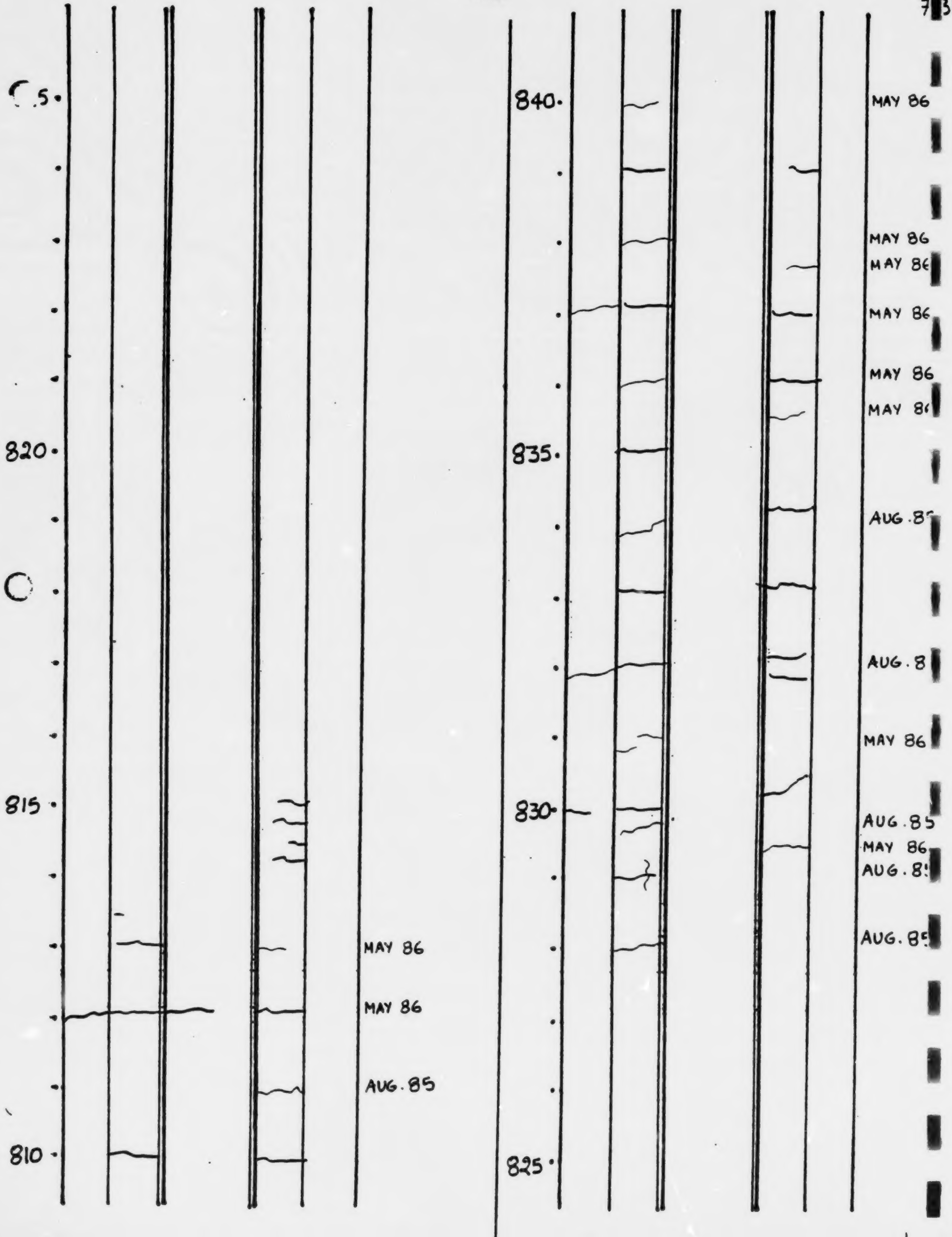
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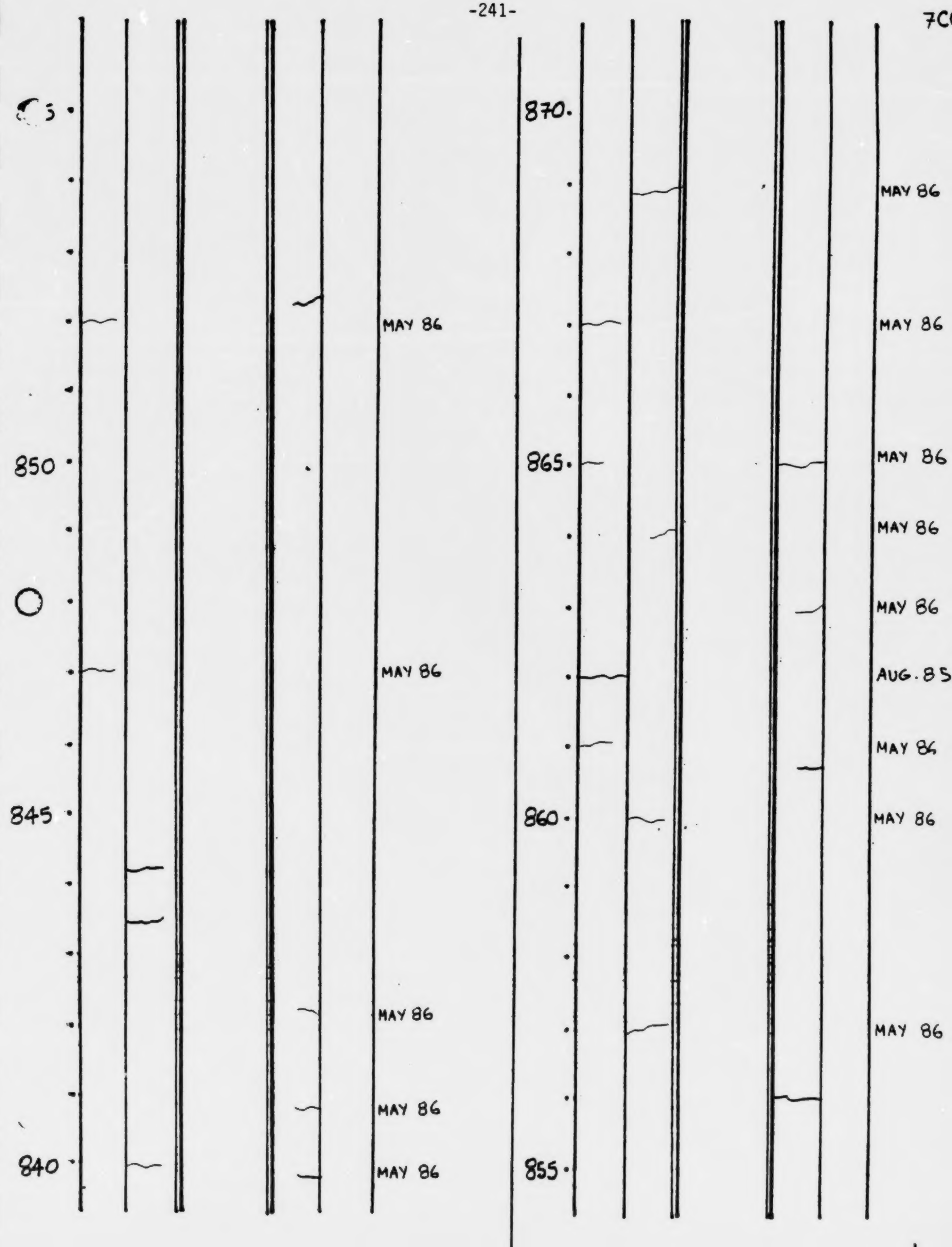
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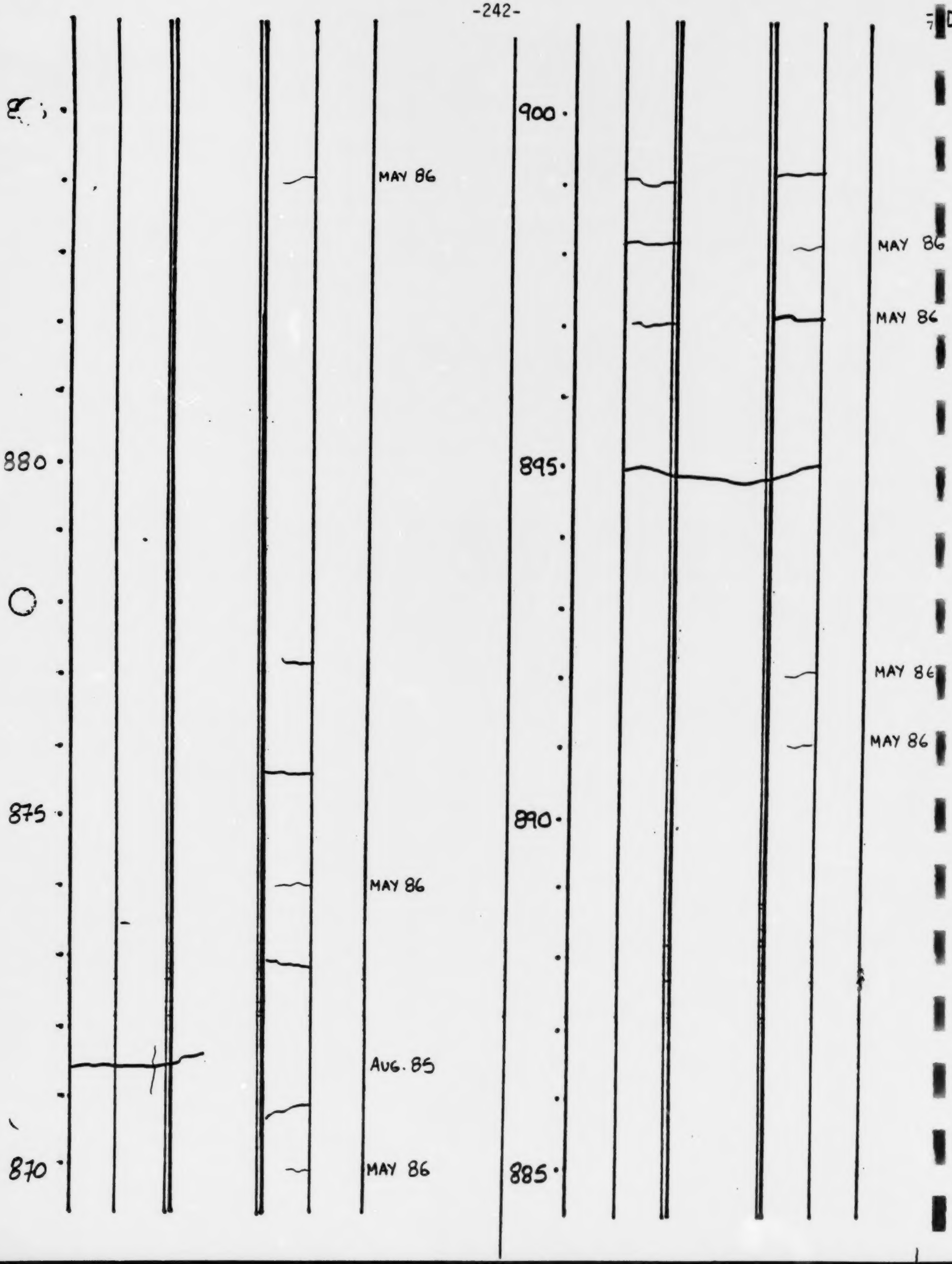
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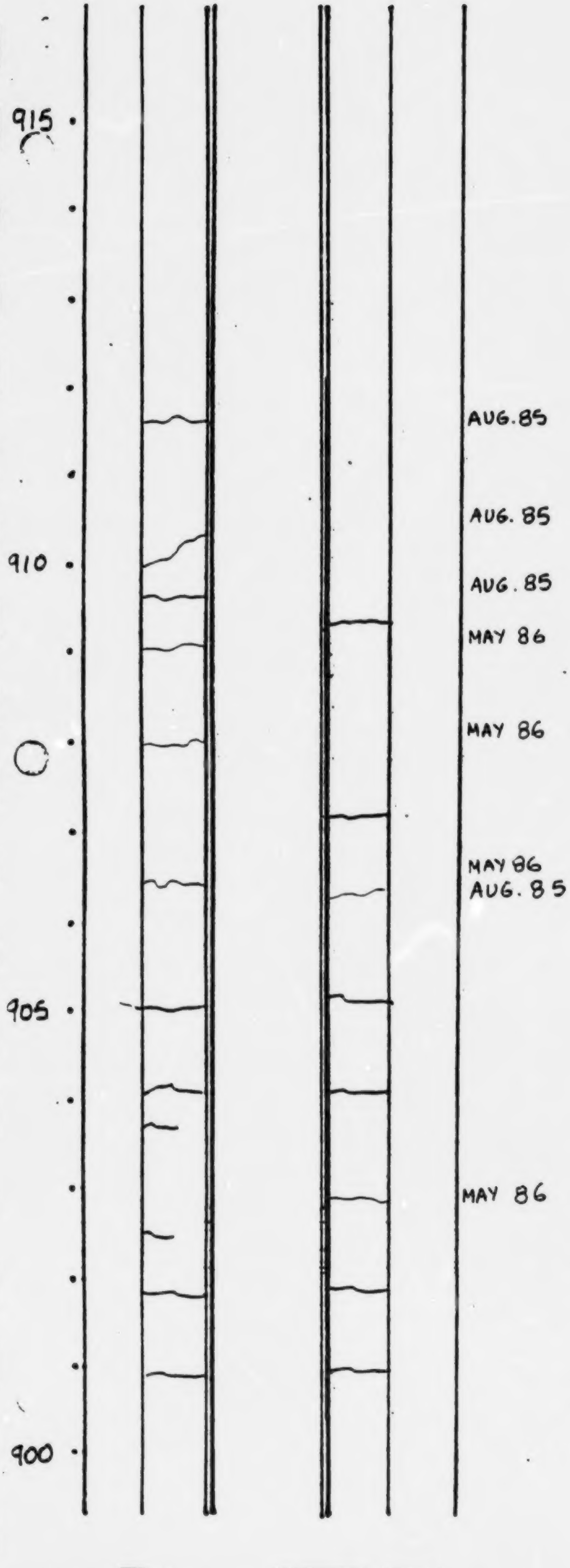
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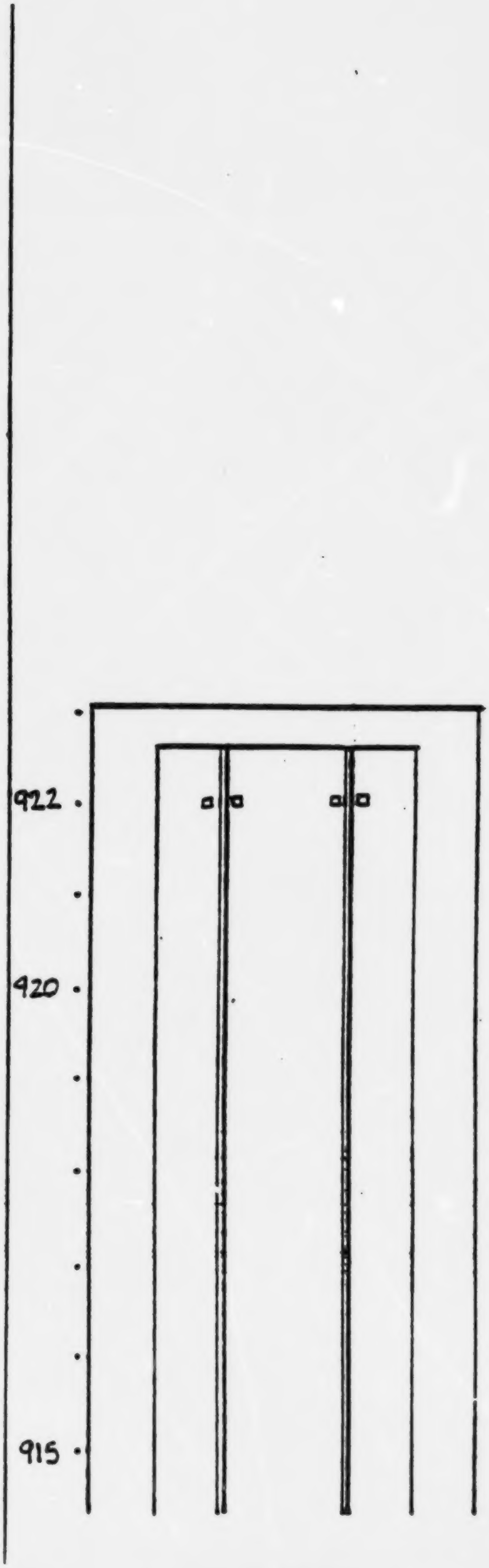


APPENDIX B

WEATHER SUMMARY

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

May 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum	20.9 °C.	Minimum	6.4 °C.	Mean	13.7 °C.
Normal	19.7	Normal	4.9	Normal	12.5

PRECIPITATION (30 year normal)

Rainfall	54.7 mm	Snowfall	cm	Total pcpn	54.7 mm
Normal	52.3	Normal		Normal	52.5

SUNSHINE (15 year normal)

Sunshine	232.6 hr.
Normal	209.3

SUMMARY

Maximum temperature 29.6 °C. on the 22nd
Record maximum 37.3 set in 1936

Minimum temperature 0.1 °C. on the 13th
Record minimum -6.7 set in 1954

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

May 1985 was much warmer and sunnier than normal, while total precipitation was about normal. The first 2 weeks were quite cool, but from the 15th to the 23rd it became nice and warm, with temperatures soaring into the high 20's, under mostly sunny skies. It started to cloud over though on the 22nd, and the weather turned for the worse on the 24th, with a veritable downpour during a thunderstorm. It stayed cool and showery until the end of the month. Afew records were broken, first on the 13th the record low mean was broken with 6.3C, by 0.1C, a record that stood since 1899. During the warm spell we broke 2 record high minimum temperatures (19th and 23rd.), and during the thunderstorm on the 24th we broke the record rainfall for the day of 10.7mm (since 1926) with a total of 14.4 mm. There were also 5 thunderstorms recorded, the highest number since 1950 for the month of May; an indication of the unstable airmass, which also caused a number of windy days throughout the month. Yet, on the whole a pleasant month, and much nicer than last year's May.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

JUNE 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum 22.7 °C. Minimum 9.2 °C. Mean 16.0 °C.
Normal 22.3 Normal 8.6 Normal 15.9

PRECIPITATION (30 year normal)

Rainfall 71.6 mm Snowfall ____ cm Total pcpn 71.6 mm
Normal 64.8 Normal ____ Normal 64.8

SUNSHINE (15 year normal)

Sunshine ~~216.8 hr.~~ 239.0
Normal ~~239.0~~ 216.8

SUMMARY

Maximum temperature 34.1 °C. on the 29th
Record maximum 36.7 set in 1925

Minimum temperature 3.9 °C. on the 9th
Record minimum -1.7 set in 1933

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

June was characterized by seasonal temperatures & slightly greater than normal rainfall. However, most of the cloudy unsettled weather occurred during the first half of the month. This gave way to sunnier and warmer conditions by the last week as a ridge of high pressure finally established itself over the province. A record 21.0 mm of rain fell on the 7th breaking the previous record,for that day, of 19.3 mm set in 1915. On the 24th a record lo mean temperature of 10.1 occurred, breaking the record of 10.6 set in 1935. While no temperatures were high enough to set new record maximums the 34.5 set on the 29th fell just short of the June record max of 36.7. In total there were 4 days with thunder reported and 10 days with peak winds over 16 knots. There were 10 days with rainfall greater than 1.0 mm, 8 of which occurred during the first half of June. Still, June was pleasant enough with an above average 239 hrs of bright sunshine.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

JULY 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum	31.2 °C.	Minimum	12.5 °C.	Mean	21.9 °C.
Normal	26.5	Normal	10.3	Normal	18.4

PRECIPITATION (30 year normal)

Rainfall	13.4 mm	Snowfall	cm	Total pcpn	13.4 mm
Normal	56.8	Normal		Normal	56.8

SUNSHINE (14 year normal)

Sunshine 348.5 hr.
Normal 259.6

SUMMARY

Maximum temperature 36.7 °C. on the 21st
Record maximum 40.6 set in 1941

Minimum temperature 8.9 °C. on the 27th
Record minimum 0.6 set in 1929

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

July 1985 will be long remembered for it's warm and sunny days. It was the warmest July since 1950, previous warmest July months were in 1958 and 1960, both with an average temperature of 21.7°C. It was also the 2nd driest July since 1950, the driest was July 1960 with only 11.2 mm. But what made it so unusual, was, that no record high temperatures were set, an indication that for the longest time during the month, it was realy warm. This is shown in the number of hours of bright sunshine, the highest since recording of sunshine began in 1970. Of course the hot weather of this July will also be remembered for the forest fires, although there were only 5 days reported with thunderstorms, most of them with little or no precipitation, except for the 23rd, when a good shower brought 7.6 mm of rain, more than half of the total for the month.
All in all an auspicious start of the summer, thanks to a persistent ridge of high pressure, which only during the last days of the month started to move eastward, allowing Pacific moist air to enter the Province.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

August 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum	30.7 °C.	Minimum	6.3 °C.	Mean	16.5 °C.
Normal	25.0	Normal	9.5	Normal	17.6

PRECIPITATION (30 year normal)

Rainfall	72.5 mm	Snowfall	cm	Total pcpn	72.5 mm
Normal	41.3	Normal		Normal	41.3

SUNSHINE (14 year normal)

Sunshine	233.6 hr.
Normal	240.1

SUMMARY

Maximum temperature 30.7 °C. on the 3rd
Record maximum 38.4 set in 1967

Minimum temperature 6.3 °C. on the 27th
Record minimum -6.1 set in 1928

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

August is typified by hot, dry weather - much like July - but it is the usual case for temperatures to slowly moderate from their July peaks and for the weather to remain dry - drier in fact than July. For the second year in a row, however, precipitation was almost double the established mean (72.5 mm vs 41.3 mm) but was well below the 1976 record of 149.4 mm. While the month began hot - with the monthly maximum temperature of 30.7° C being established on the 3rd - the trend was quickly reversed as the province came under the influence of a series of cold low pressure systems. The mean monthly temperature was almost a full degree lower than the standard 17.6° C, and a new record low maximum temperature was set for the 9th and 21st at 16.2 and 16.1° C respectively. The hours of bright sunshine were lower than average but well above last year (219.9 hours) and the lowest on record 131.8 hours in 1976. Thunderstorms were recorded on ten days this month, which is greater than normal, but these storms brought rainfall or occurred at times when the fire hazard was diminished so the threat of fire was much less than in July. There were fourteen days with winds exceeding 16 knots and two days recorded peak winds of 34 knots.

Even though this past month was cooler and considerably more moist than usual, the close to normal amount of sunshine provided a pleasant August.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

SEPTEMBER 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum 15.3 °C. Minimum 5.5 °C. Mean 10.4 °C.
Normal 19.0 Normal 6.7 Normal 12.8

PRECIPITATION (30 year normal)

Rainfall 118.1 mm Snowfall 0.0 cm Total pcpn 118.1 mm
Normal 59.4 Normal 0.1 Normal 59.5

SUNSHINE (15 year normal)

Sunshine 134.7 hr.
Normal 149.0

SUMMARY

Maximum temperature 22.2 °C. on the 2nd
Record maximum 37.3 set in 1928

Minimum temperature -1.2 °C. on the 28th & 29th.
Record minimum -6.7 set in 1926

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

September 1985 was the 2nd coldest month of September since 1950. Previous coldest was 1970, with a mean temperature of only 9.7C. On the 6th we broke the low maximum temperature record that stood since 1927, and the same happened on the 20th, when the record low maximum was broken that stood since 1955. The last one was caused by a cold airmass which crossed the Province into Alberta, leaving up to 40cm of snow in the foothills, an early reminder of winter! 2 Other records were broken, for 24 hour rainfall, one on the 6th with 26.1mm, the other with 31.9mm on the 16th. Previous records went back to 1931 and 1907 respectively. Although it was a wet month with nearly twice the normal amount of rainfall, it was not the wettest month since 1950. That was in 1969 when 152.2mm were recorded. With all the rain, our total hours of sunshine did not reach the 15 year average, but was the same as for the last 3 years, and still well above the lowest on record since recording began in 1970,; that was in 1978 with only 88.8 hours! The last 4 days were actually quite pleasant, with sunshine and clear nights, giving us a touch of frost, bringing to ~~an end~~ (a nice ending) an otherwise cloudy, wet and cool month.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

OCTOBER 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum 8.7 °C. Minimum 2.7 °C. Mean 5.7 °C.
Normal 10.3 Normal 2.7 Normal 6.9

PRECIPITATION (30 year normal)

Rainfall 150.6 mm Snowfall 18.2 cm Total pcpn 168.8 mm
Normal 82.4 Normal 0.5 Normal 83.9

SUNSHINE (14 year normal)

Sunshine 50.8 hr.
Normal 81.5

SUMMARY

Maximum temperature 15.6 °C. on the 3rd
Record maximum 25.6 set in 1932

Minimum temperature -3.8 °C. on the 8th
Record minimum -12.7 set in 1984

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:
October 1985 was much wetter, duller, cooler and windier than average, however no all time records were set. The largest departure from established normals was seen in the amount of ~~reci~~precipitation which fell (rain and snow), and the hours of bright sunshine that were recorded. 150.6 mm of rain fell with 23 days of the month recording 1 mm or more. Although this amount did not break the 1967 record of 194.8 mm, it was 55% greater than normal (82.4 mm). 18.2 cm of snow fell, usually in combination with rain or at above freezing temperatures, so that the maximum accumulation on the ground was only 3 cm on the 27th. We have to go back to 1951, to find a greater snowfall in October (30 cm). Peak winds of 30 km/hr or greater were recorded on 18 days, with 4 days reporting winds exceeding 52 km/hr. The peak wind for the month of 80 km/hr occurred during a thunderstorm on the 25th. Another thunderstorm was reported on the 19th, to give an average number of electical storms for this month. The daily mean temperature was 1.2 C below normal, due to the lack of heatingdays, rather than to ~~the~~ any significant cold weather outbreak. The daily minimum temperature was in fact normal. The maximum temperature for the month was 10 degrees cooler than the all time amximum of 25.6 C set in 1932, and the monthly low temperature was 8.9 degrees warmer than the record set last year of -12.7 C. With measurable precipitation falling on so many days this month, and with 30.7 less hours of bright sunshine, October was dull, cool and damp.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

NOVEMBER 1985 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum -3.7 ~~3.2~~ °C.
Normal 3.2

Minimum -9.0 ~~[illegible]~~ °C.
Normal -2.0

Mean -6.4 °C.
Normal 0.7

PRECIPITATION (30 year normal)

Rainfall 31.0 mm
Normal 37.1

Snowfall 38.0 cm
Normal 51.1

Total pcpn 66.0 mm
Normal 84.9

SUNSHINE (14 year normal)

Sunshine 79.5 hr.
Normal 38.6

SUMMARY

Maximum temperature 5.7 °C. on the 4th
Record maximum 17.2 set in 1975

Minimum temperature -23.6 °C. on the 28th
Record minimum -22.8 set in 1955

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

As Gretzky sets scoring records - so were temperature records set across the Province in November. Arctic air, which gripped B.C. from the 16th onward, brought bitterly cold temperatures and strong Northerly winds to Revelstoke. 25 Temperature records were set, including the all time monthly extreme low of -23.6 C on the 28th. New daily low maximum and low mean temperatures wer set on the 22nd-30th inclusive, with additional low minimum records set on the 23rd, 24th and 26th-30th. The monthly mean temperature of -6.4 C was 5.7 C cooler than normal. To find a similar outbreak of Arctic air, we have to go back to 1955, when the previous low maximum (-14.5 C), daily low mean (-21.1 C) and low minimum (-22.8 C) were set. The interesting difference between November 1955 and November 1985 is the fact that 30 years ago [illegible].6 mm of precipitation fell, the highest ever recorded for the month of November. This year 33.0 mm of precipitation fell on November 1st, a record for that day, but proved to be almost one half of the monthly total. The month's precipitation total was 18.9 mm below average but was well above the all time driest November, when 20.9 mm of precipitation fell in 1979. Winds accompanying the Arctic surge often brought the wind chill factor down to -40 C and as low as -55 C. The month was windier than normal with 19 days recording winds exceeding 30 km/hr and 5 days with winds over 52 km/hr. Another record, which offset the cold somewhat, was that of record sunshine - 79.5 hours! More than double the established mean, and well above the previous record of 65.1 hours set in 1978.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

DECEMBER 19 85 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum	-2.3 °C.	Minimum	-6.8 °C.	Mean	-4.6 °C.
Normal	-1.8	Normal	-6.2	Normal	-3.8

PRECIPITATION (30 year normal)

Rainfall	TR mm	Snowfall	70.0 cm	Total pcpn	40.8 mm
Normal	28.7	Normal	139.0	Normal	143.8

SUNSHINE (15 year normal)

Sunshine 17.1 hr.
Normal 29.9

SUMMARY

Maximum temperature 1.3 °C. on the 19
Record maximum 17.2 set in 1931

Minimum temperature -19.9 °C. on the 1
Record minimum -32.8 set in 1968

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

A ridge of high pressure covered the province for most of the month producing valley cloud and fog throughout the Interior. The main effects of this ridge were - to produce many days with little or no sunshine (valley cloud) and to cause very little precipitation to fall.

A typical December receives 29.9 hours of sunshine - this year we had 17.1 hours. December, 1969 recorded the fewest hours of sunshine with 10.4 while the brightest December on record was in 1983 with 56.8 hours of sunshine. 24 days had no sunshine (the December record is 25) and 18 of those days were in succession which beats the 1972 total of 15 in a row.

The total precipitation that fell was 40.8 mm - a record low for the month. A trace of rain was collected and only 70.0 cm of snow fell. The record low snowfall occurred in 1963 when 61.0 cm fell while the monthly mean is 139.0 cm (or twice this years total). On three days this month freezing rain was reported which is characteristic of prolonged periods of valley cloud.

The cold weather of November carried over briefly into December when the monthly minimum of -19.9 °c was recorded on the first. This trend was reversed in the first week as the ridge became stationary over the province. For the remainder of the month temperatures were close to seasonal values as the mean monthly temperature was only 0.8 degrees cooler than normal. Arecord low maximum (-9.5) and low mean (-14.7) were set for the month on the first.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

JANUARY 1986 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum 0.9 °C. Minimum -3.8 °C. Mean -1.5 °C.
Normal -3.8 Normal -9.8 Normal -6.6

PRECIPITATION (30 year normal)

Rainfall 19.0 mm Snowfall 135.6 cm Total pcpn 125.9 mm
Normal 18.9 Normal 145.2 Normal 122.0

SUNSHINE (16 year normal)

Sunshine 16.1 hr.
Normal 38.5

SUMMARY

Maximum temperature 7.0 °C. on the 10th
Record maximum 11.7 set in 1974

Minimum temperature -15.3 °C. on the 4th
Record minimum -34.5 set in 1909

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

January 1986 was another mild winter month, with a mean 5 degrees C above normal. Since 1950 only Janyary 1967 (1.1 C) and January 1958 (1.0 C) have been milder. Both rainfall and snowfall were about normal, but with the overall mild temperatures, it did not add to the already skimpy snowfall of December, and skiers had to wait for the 27th when we had our first good snowfall (23.2 cm). The mild temperatures were caused by a persistent ridge of High pressure that extended from the South, which protected us from Pacific storms, which were deflected to the North. But it also kept winds down, and as a consequence, low valley cloud formed for most of the time, screening us from the sunshine above, with the result that we recorded a record low number of hours of sunshine. Previous lowest was in 1982 with 21.0 hours of bright sunshine, and not far away ffom the all time low of 12.9 hours recorded in December 1979. (All sunshine figures are since 1970 when recording began). There were 7 days with dense fog, and only one day with winds in excess Of 50 km/hr. Apart from the sunshine, no other records were broken.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

FEBRUARY 19 86 WEATHER REMARKS

TEMPERATURE (30 year normal)

Maximum	-1.0 °C.	Minimum	-9.1 °C.	Mean	-5.1 °C.
Normal	1.1	Normal	-5.9	Normal	-2.3

PRECIPITATION (30 year normal)

Rainfall	14.0 mm	Snowfall	107.6 cm	Total pcpn	93.4 mm
Normal	49.7	Normal	76.7	Normal	89.8

SUNSHINE (16 year normal)

Sunshine 87.5 hr.
Normal 53.2

SUMMARY

Maximum temperature 6.4 °C. on the 26
Record maximum 12.8 set in 1930

Minimum temperature -19.4 °C. on the 19
Record minimum -32.2 set in 1936

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

The first half of February saw a ridge of high pressure persist along the coast, giving us mostly sunny weather and very little precipitation for nearly two weeks. A major system gave us a snowfall of 54cm over the 15/16th, but this was followed by a rebuilding of the ridge and a few more days of sunshine, cool temperatures, and sparkling powder. Another deep low moved in on the 22nd, giving us two days of snow followed by a day of rain. The Arctic air was pushed back to northern B. C. and very mild Pacific air flooded into the Interior. Freezing levels soared to over 3,000 metres and avalanches plagued the transportation system for 3 or 4 days; early spring seemed to have arrived with a vengeance. The month finished up with a continuation of the mild weather.

Statistically speaking February was cooler than normal, with below average rainfall and above average snowfall, although no temperature or precipitation records were set. Thanks to the first part of the month though, we managed to set a record number of sunshine hours, breaking the old record of 81.6 hours in 1970, the year sunshine data began. Our few windy days occurred in the middle of the month, and the peak gust was from the north at 63 km/h on the 13th.

REVELSTOKE WEATHER STATION ENVIRONMENT CANADA

March 1986 WEATHER REMARKS

TEMPERATURE (30 year normal)

Mean Maximum	7.3 °C.	Minimum	-1.2 °C.	Mean	3.1 °C.
Normal	5.0	Normal	-3.8	Normal	0.7

PRECIPITATION (30 year normal)

Rainfall	76.6 mm	Snowfall	3.2 cm	Total pcpn	79.8 mm
Normal	55.1	Normal	31.4	Normal	88.2

SUNSHINE (16 year normal)

Sunshine 86.9 hr.
Normal 108.5

SUMMARY

Maximum temperature 11.0 °C. on the 10
Record maximum 22.2 set in 1947

Minimum temperature -5.5 °C. on the 17
Record minimum -22.2 set in 1955

GENERAL DESCRIPTION OF THIS MONTH'S WEATHER:

March 1986 was quite mild, with the mean temperature almost 2.5 C above normal. This is the 4th year since 1980 that the mean has been above the 3 C mark, that is 4 out of 6 years in a row. Rainfall was well above average, but snowfall was almost non existent, and total precipitation below normal. This showed up in lack of snow on our local Ski Hill, so far the total snowfall for the season was 91 cm less than last year at this time There were 2 days with heavy rainfall, the 7th (19.8 mm) and the 24th (15.[illegible] mm). The heavy rainfall on the 7th was caused by a thunderstorm, and was the greatest rainfall for 24 hours since 1967, when 21.3 mm were recorded for one day. The other thunderstorm that was recorded on the 21st, brought less rain, but made it the most thunderstorms recorded for the month of March since 1970. In fact there was only 1 other year that thunder was heard, in 1982. The first 10 days of the month saw fog early in the morning each day, caused by a persistent ridge if high pressure, and in most cases, the fog would burn off during the day, giving sunshine for the remainder. The total of 13 days with fog was higher than in 1984 (12 days) or 1978 (12 days), but still less than the highest recorded since 1970, with 15 days in 1972. Sunshine, probably because of the many days with fog was considerably below average, and the lowest since 1976 (77.8 hours) No records were broken or set, but March brought an early end to an already mild winter.

IN-SERVICE EVALUATION OF CONCRETE BRIDGE TIES

B. de Josez
Research and Development
CP Rail
February, 1986

IN-SERVICE EVALUATION OF CONCRETE BRIDGE TIES

Bridge 24.0, located on tangent track on the Winchester Subdivision, Smith Falls Division, is a 33 foot deck plate girder span. The wooden ties on this span were replaced with prestressed concrete ties in September, 1984. To help in the future design of concrete bridge ties, three tests were performed. The first, in October, 1984, consisted of measuring strains on the ties in order to determine the distribution of axle loads among them. The results indicated that small gaps between the ties and the girders were significantly affecting the load distribution. The ties were shimmed, and a second test was performed in November, 1984, the results of which showed an improved load distribution. The report on these two tests was presented in the 1984 CP Track Train Dynamics summary report.

The third test, which is described here, was performed in October, 1985, in order to quantify the behaviour of concrete bridge ties under regular traffic. Tie life is mainly influenced by the magnitude of stress range experienced and the presence of cracks. High stress ranges and tie cracking reduce tie life. For these reasons, an in-service test was conducted on Bridge 24.0 on the Winchester Subdivision.

During the week of September 23, 1985, a total of 14 gauges were mounted on the ties. Four ties were instrumented to measure maximum bending strains; the first west end tie and three at center span of the bridge. The three adjacent ties at center span were chosen to insure a high probability of capturing impact loads due to flat wheels. The locations of the gauges are presented in Table 1 (see also Figures 1 and 2). During the last three weeks of October, 1985, data was recorded for a total of 40 trains. Recording speed was selected so that frequencies as high as 5 kHz could be captured.

Table 1 - Strain Guage Locations

Tie Number	Location	Gauge Position
1, 15 & 16	Rail seat	Top
	Rail seat	Bottom
	Center span	Top
	Center span	Bottom
17	Rail seat	Top
	Rail seat	Bottom

The test objectives were:

i) To investigate those factors which determine the fatigue life of a tie. To this end, representative gauges were selected and the signals processed with a data processor/recorder using a "level crossing" program. Results obtained will be presented in percent exceedances graphs, and will show the range of strain that a tie undergoes.

ii) To identify the characteristics of high strains due to impact loads. For this purpose, the output was processed with a dynamic signal analyser to identify high impact strains. This particular signal was then transformed to the frequency domain. These results will provide more information as to the frequency response of a tie to an impact load and the resulting amplification factor.

The results will be analysed and presented in a final report to be issued in early 1987.

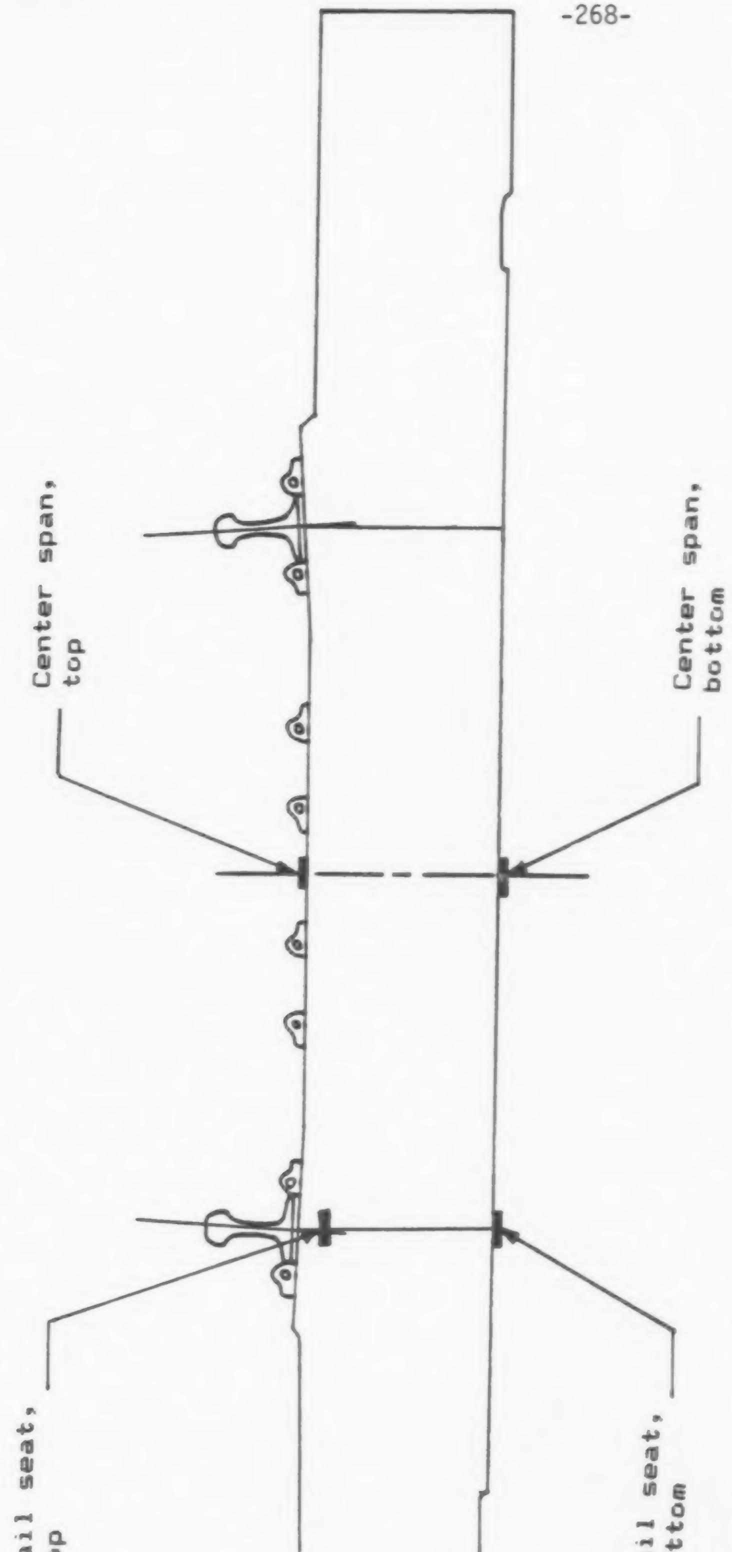
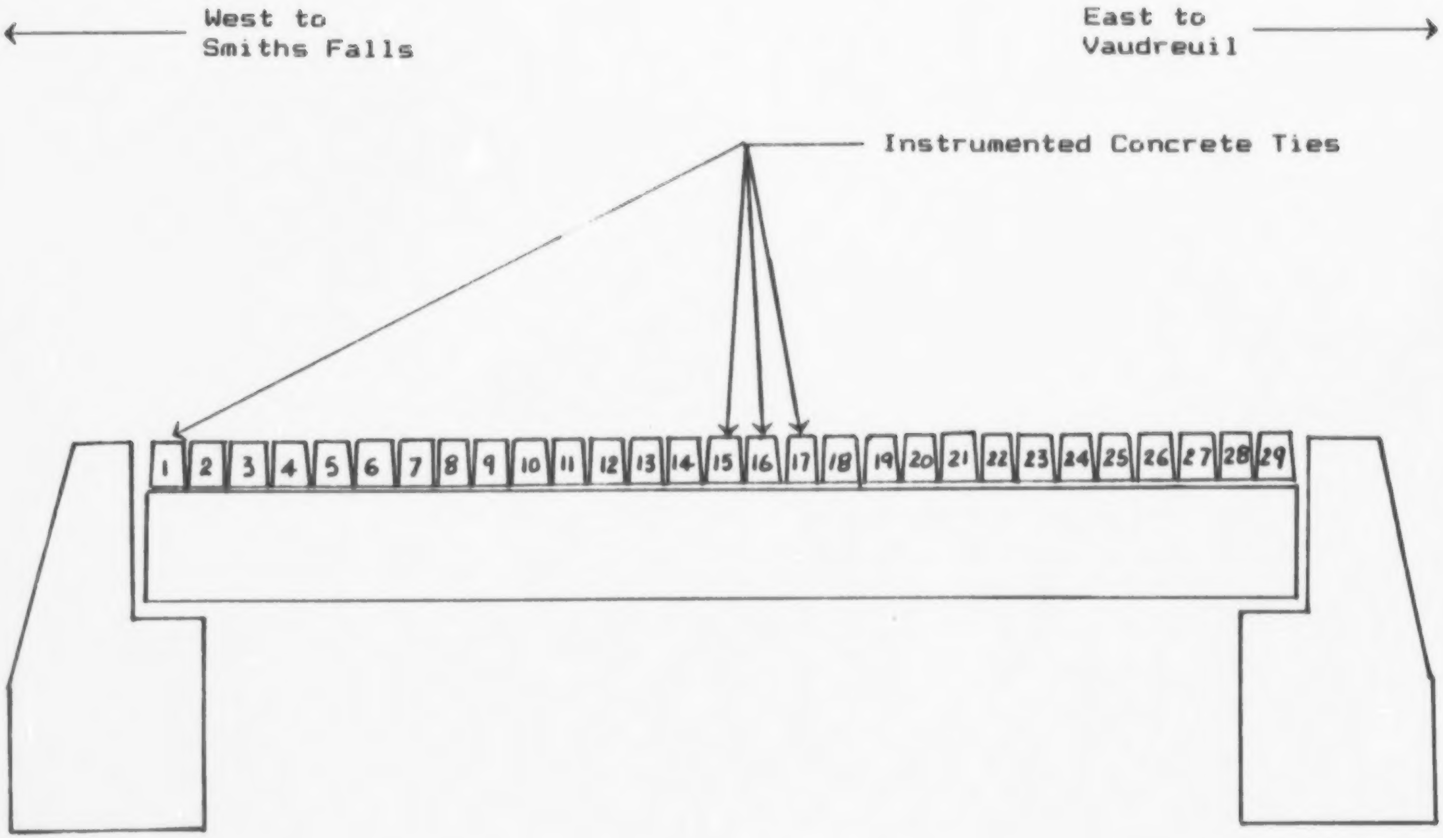

Center span, top
Center span, bottom
Rail seat, top
Rail seat, bottom

FIGURE 1: Location of strain gauges


West to
Smiths Falls
East to
Vaudreuil
Instrumented Concrete Ties
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5
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FIGURE 2: Elevation view of Bridge 24.0/Winchester Subdivision

IN-SERVICE MONITORING OF 50-TON PIGGYBACK CAR TRUCKS WITH STABILIZING DEVICES

V. Khatchadourian
Research & Development Dept.
Report No. T-929-86
December, 1986

EXECUTIVE SUMMARY

CP Rail has approximately 1300 50-ton piggyback cars in service. A program was undertaken in 1983 where one hundred and forty seven piggyback cars underwent general truck overhaul and were equipped with various types of truck stabilizing devices at CP Rail's Weston Shops in Winnipeg. Part of this program, the subject of this report, was the in-service evaluation of the effectiveness of equipping these trucks with:

- Miner Constant Contact Side Bearings (CCSBs), 25 cars
- Stucki CCSBs, 87 cars
- RDI Split Wedges and Roller Side Bearings, 10 cars
- Conventional Side Bearings and Wedges, control group, 25 cars

Ten cars from each group were selected and monitored for 200,000 miles. The Research monitoring program consisted of measurements of wheel wear, and wear of various truck components such as carbody center plates, truck bolster bowls and gibs, sideframe column plates and friction wedges.

Coincident with this monitoring program, a series of hunting tests was conducted on a car equipped with conventional trucks which were modified in the field with the service worn and new Stucki and Miner CCSBs. Results were given in

Research and Development Report No. T-931-86. In brief, it was found that the Miner equipped trucks were considerably more stable and the Stucki equipped trucks only marginally more stable than the conventional trucks. The RDI split wedges were not tested. During the tests it was observed that the high friction of the Miner CCSBs, which aided lateral stability, might prevent bolster rotation during curve negotiation in the empty car condition.

It would be expected that the increased stability of the CCSBs would reduce wear of truck components. After 200,000 miles, however, there were no significant differences in the wear of these components.

Two cars from each of the CCSB groups and one from each of the RDI and conventional groups were selected for detailed truck tear down inspection and wheel wear measurements. After 200,000 miles, six wheelsets from the Stucki group and one from each of the Miner and conventional groups had been changed-out. From the remaining wheelsets it was found that tread wear was similar for all groups. However, flange wear was higher than the conventional group by 22%, 53% and 61% for the RDI, Stucki and Miner groups, respectively. The higher flange wear with the use of these components is likely due to poor curving performance.

RDI split wedges are no longer manufactured, and there is no value in further considering them. The Miner and to a lesser extent the Stucki CCSBs increase lateral stability, thus reduce the likelihood of derailment and possibly reduce lading damage. However, their vertical stiffness increases substantially at low temperatures and wheel unloading may be experienced when traversing track spirals. It is therefore recommended that a program be undertaken to establish an improved design of a CCSB, where stability would be achieved, but where curving performance would be maintained at the highest possible level. This is likely to be more achievable with the Miner TCC-50R CCSB because it has a higher coefficient of friction at the contact surface with the carbody bolster. A lower preload is required to obtain a desired friction force, which allows for greater side bearing vertical motion for curve negotiation.

Sommaire

CP Rail opère environ 1300 wagons plats porte-remorque de 50 tonnes. Un programme de soutien a été effectué aux ateliers Weston à Winnipeg en 1983 impliquant 147 de ces wagons qui furent équipés de divers types de dispositifs de stabilisation. Trois groupes de wagons furent équipés de glissoires de traverses danseuses à contact constant des compagnies Stucki et Miner et de cales modifiées de RDI, ces dispositifs ayant été appliqués, respectivement, sur 87, 25 et 10 wagons. Un groupe de référence de 25 wagons fut équipé de paliers à roulement conventionnel.

Un élément de ce programme de soutien consistait à observer le comportement de 10 wagons de chacun des quatre groupes de wagons pour une periode équivalente à 200,000 milles de service. Ce programme d'observation, institué par le département de recherche, comprenait des mesures de profils de roues et d'usure de pièces tel que les pivots de caisses, les crapaudines, et les cales.

De plus, plusieurs essais de comportement de bogies dans les voies en alignement ont été effectués avec un wagon du groupe de référence qu'on a modifié sur les lieux avec des

glissoires de traverses danseuses à contact constant neuves et usagées des compagnies Miner et Stucki. Ces résultats se trouvent dans le rapport no. T-931-86 du département de recherche. En somme, les wagons équipés des dispositifs Miner étaient plus stables que les wagons conventionnels. Les wagons équipés de dispositifs Stucki étaient légèrement mieux que ces wagons référence. Les wagons équipés de cales modifiées n'ont pas été mis en épreuve. Ces essais indiquaient que les glissoires de traverses danseuses de Miner ont un niveau de friction élevé qui contribue d'avantage au comportement dans les voies en alignement. Cependant, cette caractéristique peut empêcher la rotation de la traverse danseuse pendant les inscriptions en courbe d'un wagon lèger.

On s'attendait que l'accroissement de stabilité des wagons équipés de ces glissoires à contact constant amenerait une baisse des taux d'usure des pièces de bogie. Malgré cela, il n'y avait aucune différence remarquable d'usure de ces pièces après 200,000 milles de service.

Des inspections approfondies et des mesures de profils de roues ont été éffectuées sur deux candidats de chaque groupe de wagons équipés de glissoires de traverses danseuses à contact constant et un candidat des groupes de wagons références et de wagons avec cales modifiées de RDI. Après 200,000 milles de service six essieux du groupe Stucki, un essieu du groupe Miner et un essieu du groupe de référence ont été remplacés. L'usure des surfaces de roulement de la balance des essieux était comparable. Les taux d'usure de boudin, par contre, des groupes RDI, Stucki, et Miner sont supérieurs à ceux du groupe de référence, respectivement, de 22%, 53% et 61%. On présume que ces augmentations d'usure de boudin sont dues à une détérioration de l'inscription en courbe de ces bogies.

On n'étudie plus les cales modifiées de RDI car elles ne sont plus fabriquées. Les glissoires de traverses danseuses à contact constant Miner, et de façon moindre, ceux de Stucki, améliorent le comportement des bogies en voies en alignement. Ceci réduira probablement les bris de marchandises et minimisera la possibilité de déraillement. Par contre, leur rigidité verticale augmente considérablement à basse température et un déchargement de roue peut se produire pendant l'inscription en courbe de raccordement. On suggère, alors, qu'un programme soit mis en place pour établir une conception améliorée de glissoires de traverses danseuses à contact constant avec lequel on peut s'assurer d'un bon comportement de bogies en voie en alignement sans compromettre leur comportement en courbe. Ceci serait possible avec le Miner TCC-50R qui a un coefficient de friction élevé à sa surface de contact avec le glissoir de caisse. Une charge initiale plus petite sera requise pour obtenir le niveau de force de friction voulu ce qui permettra un plus grand mouvement vertical des glissoires pour les inscriptions en courbes.

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1.0 INTRODUCTION

At the request of the Mechanical Department of CP Rail the Research Department initiated a monitoring program to evaluate the service performance of 50-ton piggyback car trucks equipped with various types of truck stabilizing devices. The objective of this program was to comparatively evaluate the wear of components of these trucks and detect differences due to application of these devices.

The devices which were applied to 50-ton trucks for service evaluation were Miner and Stucki constant contact side bearings and RDI split wedges. Three groups of ten piggyback test cars had their trucks equipped with Miner constant contact side bearings, Stucki side bearings or RDI split wedges, during a general truck overhaul program at Weston Shops in Winnipeg prior to test commencement starting from November 1983. A fourth group of ten piggyback cars had their trucks equipped with conventional roller type side bearings and friction wedges. The total number of test cars was forty. All test cars were identified by numbers starting from 1 to 40. They were all equipped with new 33 inch AAR profile wheels prior to release for revenue service testing.

All initial truck measurements were recorded by CP Rail Mechanical personnel at Weston Shops. Wheel profiles were collected by CP Rail Research personnel. This test program included two major inspections after 55,000 and 110,000 miles and a final truck tear down inspection after approximately 200,000 miles of revenue service operation. The present report presents wheel profiles collected after 110,000 and 200,000 miles of service and the results of truck tear down inspections carried out on samples from each test group.

2.0 DESCRIPTION OF TRUCK STABILIZING DEVICES

2.1 Miner Constant Contact Side Bearings

Miner constant contact side bearings are retrofit components which fit in the existing side bearing cage. They consist of a metal top cap attached to a rubber component housed between two metal stops. The elastomeric pad provides a preload when compressed to 5-1/16" installed height of 5,000 to 7,000 lbs depending upon the type of truck i.e. 50 or 70 ton.

2.2 Stucki Constant Contact Side Bearings

Stucki constant contact side bearings consist of replacement components which fit in the existing side bearing cage. These components are a pair of resilient blocks, a standard 4 inch diameter Stucki roller and a pair of steel cage end closures. The elastomeric pads, which in this case are directly in contact with the carbody wear plate (no metal top), are compressed to 5-1/16" installed height to provide a preload of between 5,000 to 7,000 lbs.

2.3 RDI Split Wedges

RDI split wedges are replacement components for the conventional friction wedges in a three-piece truck. They can be retrofitted to an existing truck whose bolster has been modified by the addition of pyramid shaped members to the bolster pockets which provide a bearing area for the split wedges. In this test application, they were used in conjunction with conventional roller side bearings.

This arrangement is intended to increase the warp stiffness of the truck thus increasing its hunting threshold speed.

3.0 WHEEL WEAR MEASUREMENTS AFTER 110,000 MILES OF OPERATION

Table 1 shows the results of wheel wear measurements performed after 55,000 miles of service. After approximately 110,000 miles of revenue service operation all 40 piggyback test cars were inspected by CP Research and Mechanical Department personnel in March and May 1985. Piggyback car trucks equipped with conventional roller type side bearings and wedges, Miner side bearings, Stucki side bearings and RDI split wedges had accumulated 113,000, 118,000, 118,000 and 108,000 miles, respectively. Wheel profilometer and calibrated finger gauge measurements were made. The finger gauge measurements are reported in Tables 2 to 5 and actual wheel profiles are shown in Figures 1 to 8.

Table 6 provides a summary of wheel wear after 110,000 miles for each of the groups of cars being tested. Wheel wear rates initially up to 55,000 miles of service, and at higher mileages between 55,000 and 110,000 miles, are also presented in Table 6.

4.0 OBSERVATIONS AFTER 110,000 MILES OF SERVICE OPERATION

1. Flange wear rates have significantly reduced for all groups of test cars between 55,000 and 110,000 miles. Only the Miner equipped cars, and to a lesser extent cars equipped with conventional trucks, exhibited a limited amount of additional flange wear between 55,000 and 110,000 miles.

2. RDI equipped trucks exhibit the largest flange metal loss after approximately 110,000 miles of revenue service operation. It should be noted that accelerated flange wear occurred on RDI car wheels during the first 55,000 miles of operation.

3. All test groups, with the exception of the RDI split wedge group, have experienced a reduction in their rates of tread wear between 55,000 and 110,000 miles of operation. The most significant reduction in the rate of tread wear was observed on conventional cars where the rate decreased by 40% between 55,000 and 110,000 miles of operation.

4. Within the groups of cars equipped with constant contact side bearings, the Stucki equipped cars exhibited a 33% reduction in their tread wear rate compared to a 17% reduction for the Miner cars between 55,000 and 110,000 miles of operation. The RDI cars, on the other hand, exhibited a 21% increase in tread wear rates between 55,000 and 110,000 miles of operation.

5. Cars equipped with constant contact side bearings and reference cars with conventional side bearings have experienced equivalent amounts of tread metal loss after approximately 110,000 miles of operation. The RDI cars still show the lowest amounts of tread metal loss because of their significantly lower tread wear rates during the first 55,000 miles of operation.

5.0 WORN WHEEL PROFILES AFTER 110,000 MILES OF OPERATION

Out of forty (40) test cars, eight cars (2 from each group) were monitored for wheel wear utilizing the Research Department's wheel profilometer. Worn wheel profiles from the eight cars measured after approximately 55,000 miles of revenue service operation were presented in an interim report.

Wheel profiles collected after approximately 110,000 miles of service are presented in this final report of this study in Figures 1 to 8.

Wheel profiles shown in Figures 1 to 8 illustrate that wheels of trucks equipped with constant contact side bearings have experienced greater flange metal losses than conventional trucks. The tread wear on both Miner and Stucki equipped trucks are similar; these wheels all show a considerable amount of tread hollowness after 110,000 miles. Conventional truck wheel treads also experienced wear and developed a hollow shape. The RDI trucks, which experienced the least amount of wheel tread metal loss after 55,000 miles, have now experienced considerable wheel tread wear. Wheels from one RDI equipped car were not hollow, as can be seen in Figure 7, whereas wheels from another were, Figure 8. The reason for this difference is not known.

The most uneven wear on the wheel flanges and treads is observed on car CP 504599 equipped with the Stucki device. The most wheel changeouts have also occurred on the Stucki equipped test car CP 504019.

6.0 TRUCK TEAR DOWN INSPECTIONS

After approximately two years of service operation, piggyback cars CP 504722, CP 504249, CP 504599, CP 504019, CP 505345 and CP 504605 underwent complete truck tear down inspections. The first four piggyback car trucks were inspected at CP Rail's

Angus Shops and the last two were inspected at the St. Luc Car Shop. Figure 9 shows piggyback test car CP 504019 equipped with the Stucki constant contact side bearings during truck tear down inspection at CP Rail's Angus Shops in March, 1986. Figure 10, shows the 'B' end truck of car CP 504019 during the truck tear down inspection. The truck is shown with new Stucki pads applied after tear down and prior to final assembly. The reason for removal of the older Stucki pads was to evaluate the condition of the Stucki pads after 193,000 miles of service operation.

In total, twelve trucks were fully torn down and truck measurements taken together with wheel wear measurements. Four such trucks were equipped with the Miner constant contact side bearings. The next four were trucks equipped with the Stucki constant contact side bearings. Four other trucks, two with conventional side bearings and another two with RDI split wedges, were also torn down and fully inspected.

The results of wheel wear measurements as well as carbody centre plate and truck bolster bowl wear measurements, side frame column wear and bolster gib wear measurements are shown in Tables 7 to 13.

7.0 TEAR DOWN OF TRUCKS EQUIPPED WITH CONSTANT CONTACT SIDE BEARINGS

Two piggyback cars, CP 504722 and CP 504249, equipped with the Miner devices and two others, CP 504599 and CP 504019, equipped with the Stucki devices underwent full truck tear down inspections at CP Rail's Angus Shops in March, 1986.

These cars were monitored from day one when new wheel profiles were taken prior to their introduction into revenue testing. Wheel wear data indicate that the cars equipped with Miner devices have had only one wheelset changeout as compared to six wheelset changeouts for two test cars equipped with Stucki devices. The wheel wear data are shown in Tables 7 and 8.

Figures 11 and 12 show the typical condition of the Stucki and Miner devices after approximately 200,000 miles of service. Shims inserted to provide control over the longitudinal displacement of the Miner devices were typically damaged and required replacement after 200,000 miles. The Stucki devices were not broken; however, free height measurements indicated that some permanent setting had occurred.

It was not known how the increase in longitudinal slack of the Miner device, due to failure of the shims, and the loss of preload of the Stucki device, due to the permanent set, would affect the high speed stability performance of the piggyback cars equipped with these devices -- particularly when combined with the effect of the worn wheel profile. A field test was carried out to provide some of these answers. This is discussed in Section 9.0.

Data as tabulated in Tables 9 to 13 indicate that there is no appreciable difference in component wear between Miner and Stucki equipped trucks. However, wheel changeouts on Stucki equipped cars are more frequent, which may have resulted in these truck having, on average, greater lateral stability. This would reduce component wear.

Figures 13 and 14 illustrate typical bolster bowl and gib wear after 200,000 revenue miles for trucks equipped with either Miner or Stucki devices. The truck bolster bowl wear is approximately 1/8" and the bolster gib wear is generally 1/16 to 1/8" (See Tables 10 and 13).

Figure 15 shows the profile of a wheel from CP 504722 (equipped with the Miner constant contact side bearings), after 207,000 miles of revenue service testing. Profiles of other wheels on this car, as well as from other test cars equipped with Miner devices, are contained in Appendix A.

8.0 TEAR DOWN INSPECTIONS OF THE RDI AND CONVENTIONAL TRUCKS

Two other piggyback test cars, CP 505345 equipped with the RDI split wedges and CP 504605 equipped with conventional roller type side bearings and wedges, underwent complete truck tear down inspections in May 1986 at the St. Luc Car Shops.

The results of the truck tear down inspections are presented in Tables 7 to 10. Here, again, there was no appreciable difference in the wear of the truck components of these two types of trucks.

Wheels from RDI equipped trucks have experienced less wear than wheels from conventional trucks. However, the mileage accumulated on the RDI trucks (166,000 miles) was lower than on the conventionally equipped trucks (185,000 miles); hence, a direct comparison cannot be made.

9.0 FIELD TESTING OF PIGGYBACK CARS EQUIPPED WITH MINER AND STUCKI CONSTANT CONTACT SIDE BEARINGS

A comparison of the Miner and Stucki truck tear down wear measurements revealed that there were not appreciable differences in wear of components such as the carbody centre plate and truck bolster bowl (typically 1/16" to 1/8" wear after approximately 200,000 miles of service). Truck bolster gib wear was also found to be similar for both Miner and Stucki equipped trucks.

Wheel changeouts on trucks equipped with Stucki constant contact side bearings was higher than that of those equipped with Miner devices. It was decided to carry out field testing with these two devices to determine their effect on high speed stability performance.

CP 504249 was chosen as the test car and high speed tests were conducted. This car had accumulated 200,000 miles of service with no wheelset changeouts. It was jacked between tests and its trucks were equipped with Stucki, and then Miner devices in both new and worn conditions. The test methodology and results are documented in a separate CP Rail Research report(1). The results indicated that the high speed performance of trucks equipped with the Miner device is superior to those equipped with Stucki devices. Neither Stucki nor Miner devices in an 'as is' condition provided stability to 65 mph.

10.0 SUMMARY OF WHEEL WEAR EVALUATION AND 200,000 MILE TEAR DOWN INSPECTION

A) AFTER APPROXIMATELY 55,000 MILES OF SERVICE OPERATION

1 - Miner and Stucki constant contact side bearings performed nearly identically with respect to tread wear. Compared to cars equipped with conventional roller type side bearings and friction wedges, there was very slight tread wear reduction.

2 - Flange wear on cars equipped with Miner constant contact side bearings was higher than that on Stucki equipped cars. Both Miner and Stucki equipped car wheels exhibited higher flange wear than cars equipped with conventional trucks.

3 - Trucks with RDI split wedges exhibited a 40% reduction in tread wear but a 60% increase in flange wear compared to conventional trucks.

B) BETWEEN 55,000 AND 110,000 MILES OF SERVICE OPERATION

1 - A significant reduction in the rate of flange wear occurred on all groups of test cars.

2 - RDI equipped cars exhibited the largest amount of flange metal loss after 110,000 miles. Miner and Stucki equipped truck wheels experienced more flange metal loss than conventional truck wheels. The wear difference between the Stucki and conventional truck wheels had narrowed after 110,000 miles.

3 - All test groups, with the exception of the RDI trucks, experienced a reduction in their rate of tread wear. The RDI equipped cars exhibited a 21% increase in their tread wear rates. Even with these increased wear rates, they exhibited the lowest amount of tread metal loss of all the test groups.

4 - Cars equipped with constant contact side bearings exhibited higher amounts of tread metal loss compared to conventional truck wheels after approximately 110,000 miles of operation.

C) AT 200,000 MILES OF SERVICE

1 - Carbody centre plate wear on cars equipped with CCSBs appeared to be slightly higher than conventional trucks and RDI equipped cars. The wear of the centre plate on conventional and RDI trucks was of the order of 1/16" compared to 1/8" for trucks equipped with CCSBs. Bolster bowl wear was found to be similar for all types of trucks and it varied between 1/16" to 3/16".

2 - Side frame column wear and friction wedge wear indicated that some cars have reached and surpassed the condemning limit of 13 3/8" specified by the AAR. Some cracked column wear plates were observed during tear down inspections. These cracks were attributed to casting deformation.

3 - Wheel changeouts on Stucki equipped cars are more frequent than for Miner equipped cars. The poorer wheel performance for Stucki equipped trucks may be attributed to poorer high speed truck stability, as observed during recent tests carried out with service worn wheels. (Reference CP Rail Report No. T-931-86).

4 - The RDI equipped piggyback car trucks performed relatively well compared to conventional truck equipped cars with respect to wheel wear. Wheel tread wear was slightly lower compared to conventional but flange wear was higher with RDI trucks. The split wedges did not show any sign of damage or excessive wear when inspected during tear down.

11.0 CONCLUSIONS AND RECOMMENDATIONS

1 - Detailed wheel and truck component wear measurements carried out on selected cars, from each group, showed that after 200,000 miles the tread wear is similar for all groups. However, flange wear was higher for the RDI, Stucki and Miner groups, compared to conventional, by 22%, 53% and 61%, respectively. The higher flange wear with the use of these devices is likely due to poor curving performance.

2 - A series of high speed stability tests conducted on one of the monitored piggyback cars, CP 504249 with service worn wheels, showed that the Miner CCSBs are more effective in stabilizing the conventional truck as compared to the Stucki CCSBs which only marginally improved conventional truck's high speed stability performance.

3 - It was expected that the increased stability of the CCSBs would reduce wear of truck components. After 200,000 miles, however, there were no significant differences in the wear of these components.

4 - The Miner and to a much lesser extent the Stucki CCSBs increase lateral stability, thus reduce the likelihood of derailment. Conventional trucks, particularly those with sideframe column width dimensions near condemning, (AAR condemning is 13 3/8") permit the trucks to losenge to a greater degree resulting in a lower hunting threshold speed compared to a new refurbished truck. Hence, continued operation with such trucks will likely result in accelerated wear of truck components.

5 - It is therefore recommended that a program be undertaken to establish an improved design of CCSB, where stability would be achieved, but where curving performance would be maintained at the highest possible level. This is likely to be more achievable with the Miner (TCC-50R) CCSB because it has a higher coefficient of friction at the contact surface with the carbody bolster. The urethane block would allow for reduced vertical stiffness to get effective side bearing clearance while maintaining the friction force for truck hunting control.

REFERENCES

1. W. Pak, V. Khatchadourian and B. de Josez, "High Speed Stability and Laboratory Component Test Evaluation of Miner and Stucki Constant Contact Side Bearings on 50-Ton Piggyback Flat Car CP 504249", Research and Development Department, CP Rail, Report No. T-931-86, October, 1986.

TABLE 1: Summary of Wheel Wear Measurements After Approximately 55,000 Miles of Operation

Test Group	Average Miles	Flange Wear (Inches)	Tread Wear (Inches)	Avg. Flange Wear Rate Per 10,000 Miles (Inches)	Avg. Tread Wear Rate Per 10,000 Miles (Inches)
Conventional Side Bearings	52,920	.089	.106	.0168	.0201
Miner Side Bearings	51,790	.123	.098	.0237	.0190
Stucki Side Bearings	55,281	.102	.104	.0184	.0188
RDI Split Wedges	56,982	.152	.068	.02675	.0120

TABLE 2: Piggyback Cars Equipped with Roller Type Side Bearings - Wheel Wear Results Obtained with the Use of a Finger Gauge

Test Car	Car Number	Accumulated (Miles)	Average Flange Wear (Inches)	Average Tread Wear (Inches)
01	CP504605	114,228	.0375	.199
02	CP505012	117,773	.1125	.160
03	CP505170	125,244	.084	.215
04	CP505054	99,842	.075	.201
05	CP505505	88,557	.0875	.140
06	CP505004	29,498	.058	.122
07	CP505005	56,839	.119	.115
08	CP505519	80,369	.106	.144
09	CP504483	143,664	.1375	.170
10	CP505217	132,055	.089	.195
Average of all test cars in this group		112,716	.091	.178

Notes: 1. Data obtained during second scheduled piggyback car inspection carried out in May 1985 at CP Rail's Lachine Intermodal Yard.

2. Data from test cars CP 505004 and CP 505005 are not included in computations of group average wheel wear because of relatively low mileage.

TABLE 3: Piggyback Cars Equipped With Miner Side Bearings - Wheel Wear Results Obtained with the Use of a Finger Gauge

Test Car	Car Number	Accumulated Mileage(Miles)	Average Flange Wear (Inches)	Average Tread Wear (Inches)
11	CP 504722	132,560	.153	.236
12	CP 504249	114,503	.1375	.225
13	CP 505295	102,701	.141	.129
14	CP 504159	139,255	-	-
15	CP 505330	117,392	.108	.203
16	CP 505986	25,803	.140	.216
17	CP 505620	95,769	.172	.135
18	CP 505309	121,963	.143	.229
19	CP 505080	123,399	.128	.225
20	CP 505283	127,924	.118	.218
Average of all test cars in this group		118,000	.138	.202

Notes: 1. Data obtained during second scheduled piggyback car inspection carried out in April 1985 at CP Rail's Lachine Intermodal Yard.

2. Data on test car CP 504159 are not available because this test car was converted to conventional roller type side bearings.

3. Data on test car CP 505330 are for 3 wheelsets only because 4 axle 1 wheels were changed out.

TABLE 4: Piggyback Cars Equipped With Stucki Side Bearings - Wheel Wear Results Obtained With the Use of a Finger Gauge

Test Car	Car Number	Accumulated Mileage(Miles)	Average Flange Wear (Inches)	Average Tread Wear (Inches)
21	CP 504599	114,090	.134	.216
22	CP 504019	134,951	.093	.207
23	CP 505063	129,841	.068	.203
24	CP 505209	134,211	.162	.119
25	CP 505160	109,356	.075	.179
26	CP 505376	108,235	.075	.213
27	CP 505280	112,482	.056	.234
28	CP 505247	97,841	.131	.127
29	CP 505314	133,149	.111	.215
30	CP 504061	105,435	.150	.183
Average of all test cars in this group		117,959	.098	.183

Notes: 1. Data obtained during second scheduled piggyback car inspection carried out in April 1985 at CP Rail's Lachine Intermodal Yard.

2. Data on CP 504019 are for 'B' end truck only. 'A' end truck wheelsets were changed out.

3. Data on CP 505280 are for 'A' end truck only. 'B' end truck wheelsets were changed out.

TABLE 5: Piggyback Cars Equipped with RDI Split Wedges - Wheel Wear Results Obtained with the Use of a Finger Gauge

Test Car	Car Number	Accumulated Mileage(Miles)	Average Flange Wear (Inches)	Average Tread Wear (Inches)
31	CP 505345	99,104	.155	.117
32	CP 505618	89,039	.140	.193
33	CP 505552	106,865	.133	.111
34	CP 505621	133,964	.170	.152
35	CP 505567	109,122	.134	.166
36	CP 505590	115,976	.140	.135
37	CP 505249	114,475	.189	.115
38	CP 505208	106,369	.175	.123
39	CP 505117	101,771	.144	.104
40	CP 505332	102,969	.096	.207
Average of all test cars in this group		107,965	.1476	.142

Notes: 1. Data obtained during second scheduled piggyback car inspection carried out in May 1985 at CP Rail's Lachine Intermodal Yard.

TABLE 6A: Summary of Wheel Wear Measurements
After Approximately 110,000 Miles of Operation

Test Group	Average Mileage	Flange Wear (Inches)	Tread Wear (Inches)	Avg. Flange Wear Rate Per 10,000 Miles	Avg. Tread Wear Rate Per 10,000 Miles
Conventional Side Bearings	113,000	.091	.178	.0080	.0157
Miner Side Bearings	118,000	.138	.202	.0117	.0171
Stucki Side Bearings	118,000	.098	.183	.0083	.0155
RDI Split Wedges	108,000	.147	.142	.0136	.0131

TABLE 6B: Summary of Wheel Wear Measurements After Approximately 200,000 Miles of Operation

Test Group	Average Mileage	Flange Wear (Inches)	Tread Wear (Inches)	Avg. Flange Wear Rate Per 10,000 Miles	Avg. Tread Wear Rate Per 10,000 Miles
Conventinal Side Bearings	185,000	.091	.2911	.0049	.0157
Miner Side Bearings	199,000	.164	.3345	.0082	.0168
Stucki Side Bearings	193,000	.150	.3082	.0077	.0159
RDI Split Wedges	166,000	.103	.2222	.0062	.0134

Note: Wheel wear data are for wheels which remained in-service after approximately 190,000 miles.

The flange wear value for the RDI-equipped trucks after 166,000 miles was less than previously measured after 108,000 miles. This is because the reference point for the flange wear measurement changed significantly with increased tread wear.

TABLE 7: Piggyback Cars Equipped with Miner, Stucki, RDI and Conventional Roller Type Side Bearings: Wheel Wear (Flange Height Loss) Results Obtained by the Use of a Calibrated AAR Finger Gauge

Increase in Flange Height (Inches)
Wheelset Position

			'B' End				'A' End			
Car No.	Device	Mileage	R1	L1	R2	L2	R3	L3	R4	L4
CP504722	Miner	207,000	22/64 (.343)	21/64 (.328)	20/64 (.3125)	14/64 (.218)	5/64* (.078)	7/64* (.109)	19/64 (.296)	21/64 (.328)
CP504249	Miner	191,000	22/64 (.343)	26/64 (.406)	19/64 (.296)	18/64 (.281)	25/64 (.390)	26/64 (.406)	26/64 (.406)	25/64 (.390)
CP504599	Stucki	183,000	7/64* (.109)	7/64* (.109)	15/64* (.234)	12/64* (.187)	12/64* (.015)	1/64* (.015)	11/64* (.171)	10/64* (.156)
CP504019	Stucki	193,000	16/64 (.250)	17/64 (.265)	26/64 (.406)	20/64 (.312)	8/64* (.125)	8/64* (.125)	11/64* (.171)	10/64* (.156)
CP505345	RDI	166,000	13/64 (.203)	15/64 (.234)	17/64 (.265)	15/64 (.234)	19/64 (.296)	10/64 (.156)	12/64 (.187)	13/64 (.203)
CP504605	Conv.	185,000	14/64 (.218)	25/64 (.390)	18/64 (.281)	15/64 (.234)	14/64* (.218)	15/64* (.234)	25/64 (.390)	15/64 (.234)

Note: * Denotes Wheelset Changed Out

TABLE 8: Piggyback Cars Equipped With Miner, Stucki, RDI and Conventional Roller Type Side Bearings: Wheel Wear Results Obtained by the Use of a Calibrated AAR Finger Gauge

Loss in Flange Thickness (inches)
Wheelset Position

			'B' End				'A' End			
Car No.	Device	Mileage	R1	L1	R2	L2	R3	L3	R4	L4
CP 504722	Miner	207,000	.250	.075	.175	.200	.225*	.150*	.250	.250
CP 504249	Miner	191,000	.125	.275	.075	.200	.150	.025	.150	.025
CP 504599	Stucki	183,000	.200*	.150*	.150*	.275*	.225*	.200*	.150*	.075*
CP 504019	Stucki	193,000	.250	.225	.100	.025	.275*	.175*	.250*	.100*
CP 505345	RDI	166,000	.100	.075	.150	.025	.150	.075	.125	.125
CP 504605	Convent.	185,000	.100	.150	.075	.025	.100*	.100	.175	.025

Note: * Denotes wheelset changed out.

TABLE 9: Piggyback Cars Equipped With Miner, Stucki, RDI & Conventional Type Side Bearings: Truck Bolster Bowl Wear Results

Truck Bolster Bowl Wear (inches)
Bolster Bowl Position

			'B' End Truck				'A' End Truck			
Car No.	Device	Mileage	Long Dia	Lat Dia	AAR Cond Limit	Difference between Max Dia & AAR Limit	Long Dia	Lat Dia	AAR Cond Limit	Difference between Max Dia & AAR Limit
CP 504722	Miner	207,000	12 5/16	12 3/16	12 7/8	9/16	12 1/8	12 1/8	12 7/8	3/4
CP 504249	Miner	191,000	12 1/8	12 1/16	12 7/8	3/4	12 3/16	12 1/8	12 7/8	11/16
CP 504599	Stucki	183,000	12 1/8	12 3/16	12 7/8	11/16	12 3/16	12 3/16	12 /78	11/16
CP 504019	Stucki	193,000	12 7/32	12 3/16	12 7/8	21/32	12 1/4	12 1/8	12 7/8	5/8
CP 505345	RDI	166,000	12 1/16	12 1/16	12 7/8	13/16	12 1/16	12 1/16	12 7/8	13/16
CP 504605	Convent.	185,000	12 1/16	12 1/8	12 7/8	3/4	12 1/16	12 3/16	12 7/8	11/16

TABLE 10: Piggyback Cars Equipped with Miner, Stucki, RDI and Conventional Type Side Bearings: Car Body Centre Plate Wear Results (inches)

			'B' End Truck				'A' End Truck			
Car No.	Device	Mileage	Long Dia	Lat Dia	Difference between bolster and centre plate Diameters	AAR Cond Limit	Long Dia	Lat Dia	Difference between bolster and centre plate Diameters	AAR Cond Limit
CP 504722	Miner	207,000	11 5/8	11 11/16	11/16	1 3/8	11 11/16	11 5/8	1/2	1 3/8
CP 504249	Miner	191,000	11 11/16	11 11/16	7/16	1 3/8	11 5/8	11 11/16	9/16	1 3/8
CP 504599	Stucki	183,000	11 3/4	11 5/8	9/16	1 3/8	11 5/6	11 21/32	9/16	1 3/8
CP 504019	Stucki	193,000	11 5/8	11 11/16	19/32	1 3/8	11 3/4	11 7/8	1/2	1 3/8
CP 505345	RDI	166,000	11 23/32	11 11/16	3/8	1 3/8	11 23/32	11 3/4	11/32	1 3/8
CP 504605	Convent.	185,000	11 11/16	11 3/4	3/8	1 3/8	11 23/32	11 3/4	1/32	1 3/8

TABLE 11: Piggyback Cars Equipped With Miner Constant Contact Side Bearings: Truck Side Frame Column Wear Results

Distance Between Column Wear Plates (inches)

Location where measurement was taken	Test Car CP 504722				Test Car CP 504249			
	'B' End Truck		'A' End Truck		'B' End Truck		'A' End Truck	
	Left	Right	Left	Right	Left	Right	Left	Right
Top across wear plates (worn)	13 3/16	13 5/16	13 9/16	13 1/4	13 5/16	13 3/16	13 5/16	13 7/16
Bottom across wear plates (worn)	13 1/8	13 3/16	13 1/2	13 1/8	13 1/4	13 1/4	13 1/4	13 3/8
Toe in	1/16	1/8	1/16	1/8	1/16	1/16	1/16	1/16
AAR allowable toe in	1/6	1/16	1/16	1/16	1/16	1/16	1/16	1/16
Mean across wear plates (worn)	13 5/32	13 1/4	13 17/32	13 3/16	13 9/32	13 7/32	13 9/32	13 3/16
Mean across wear plates (when refurbished Nov. 1983)	13 1/16	13 3/16	13 9/16	13 3/16	13 3/16	13 5/32	13 1/8	13 3/16
Side frame column wear	3/32	1/16	-	-	3/32	1/16	5/32	7/32

TABLE 12: Piggyback Cars Equipped With Stucki Constant Contact Side Bearings: Truck Side Frame Column Wear Results

Distance Between Column Wear Plates (inches)

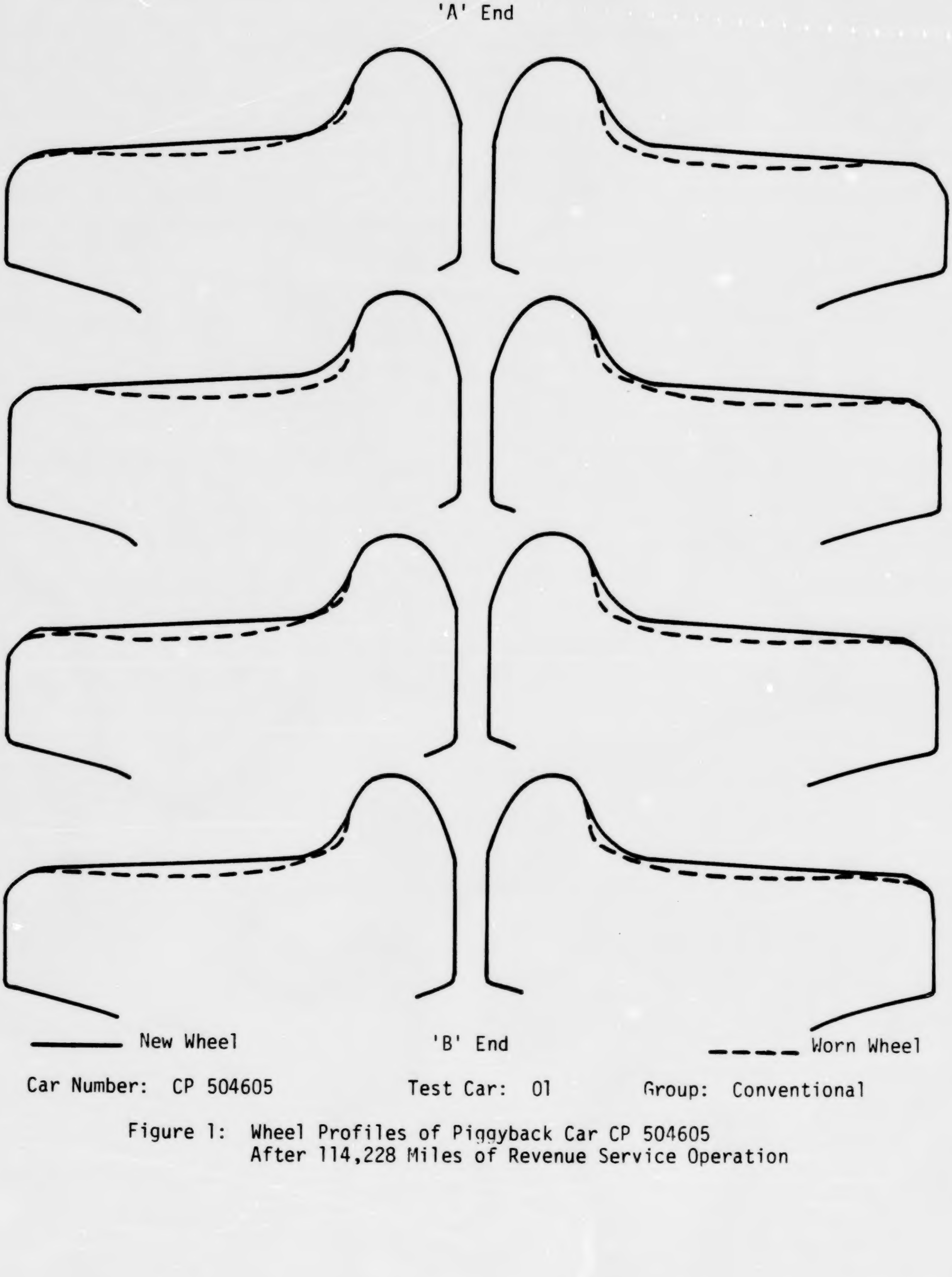
	Test Car CP 504599				Test Car CP 504019			
	'B' End Truck		'A' End Truck		'B' End Truck		'A' End Truck	
Location where measurement was taken	Left	Right	Left	Right	Left	Right	Left	Right
Top across wear plates (worn)	13 5/8	13 5/16	13 5/16	13 1/4	13 7/16	13 3/8	13 3/8	13 5/16
Bottom across wear plates (worn)	13 9/16	13 1/4	13 1/4	13 1/8	13 5/16	13 3/8	13 5/16	13 1/4
Toe in	1/16	1/16	1/16	1/8	1/8	None	1/16	1/16
AAR Allowable toe in	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16
Mean across wear plates (worn)	13 19/32	13 9/32	13 9/32	13 3/16	13 3/8	13 3/8	13 11/32	13 9/32
Mean across wear plates (when refurbished Nov. 1983)	13 3/8	13 1/4	13 1/8	13 1/8	13 3/8	13 3/8	13 1/4	13 1/4
Side frame column wear	7/32	1/32	5/32	1/16	-	-	3/32*	1/32*

* Broken wear plates.

TABLE 13: Piggyback Cars Equipped With Miner, Stucki, RDI and Conventional Roller Type Side Bearings: Truck Bolster Gib Wear Data

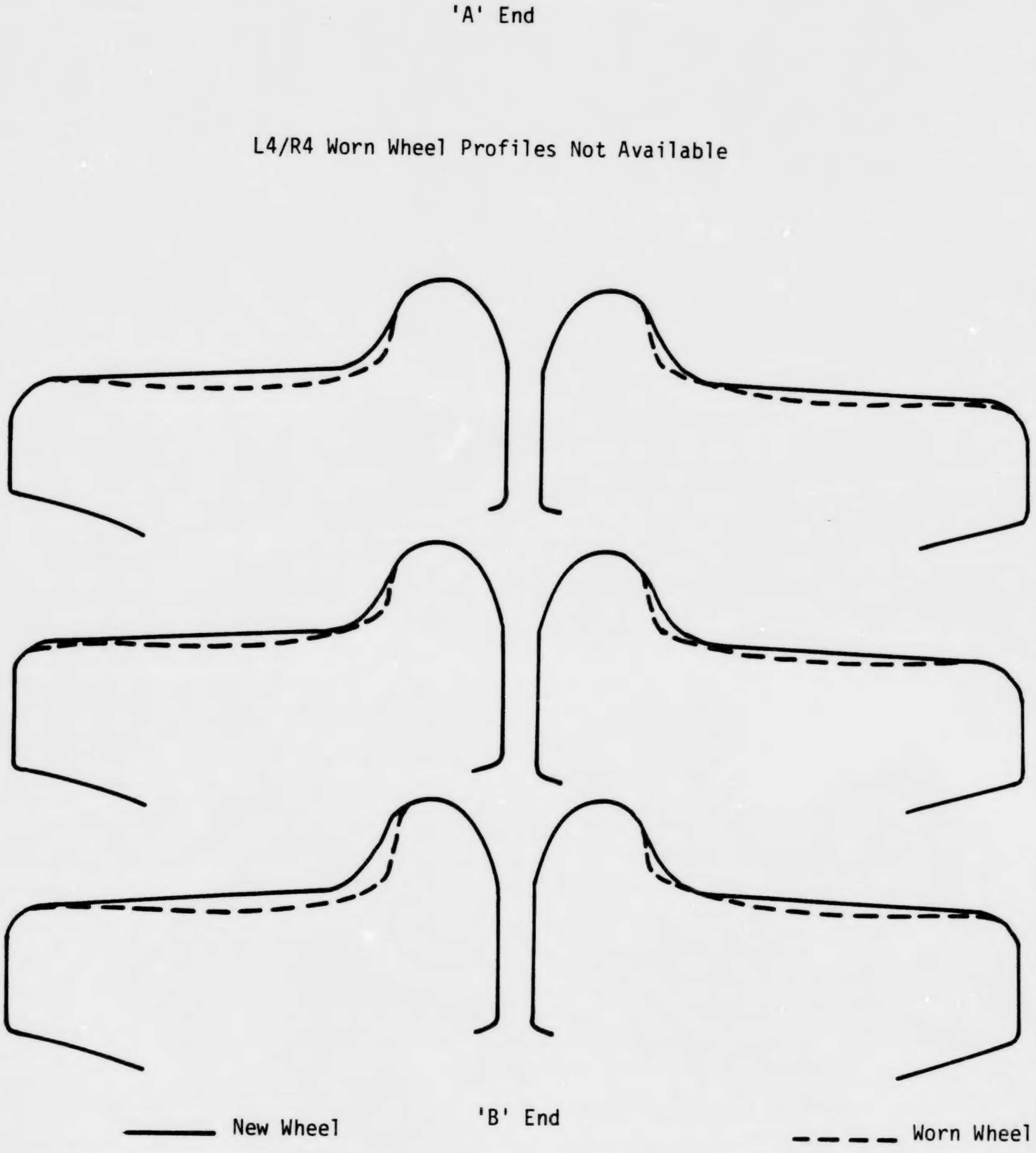
Truck Bolster Gib Wear Data (inches)

Test Car	Device	Mileage	'B' End Truck				'A' End Truck			
			Loc L1	Loc R1	Loc L2	Loc R2	Loc L3	Loc R3	Loc L4	Loc R4
CP 504722	Miner	207,000	1/8	3/16	1/8	1/8	1/8	3/16	1/8	3/16
CP 504249	Miner	191,000	None	1/8	1/8	1/8	1/16	1/8	1/16	1/16
CP 504599	Stucki	183,000	1/8	3/16	None	1/16	1/16	1/16	1/16	1/16
CP 504019	Stucki	193,000	None	1/16	1/16	None	3/16	1/8	1/8	1/16
CP 505345	RDI	156,000	None	None	1/16	None	1/16	1/16	1/16	1/16
CP 504605	Convent.	185,000	1/16	1/8	1/16	1/8	1/8	Zero	1/8	1/16


'A' End
New Wheel
'B' End
Worn Wheel

Car Number: CP 504605 Test Car: 01 Group: Conventional

Figure 1: Wheel Profiles of Piggyback Car CP 504605 After 114,228 Miles of Revenue Service Operation


'A' End
L4/R4 Worn Wheel Profiles Not Available
'B' End
New Wheel
Worn Wheel

Car Number: CP 505012 Test Car: 02 Group: Conventional

Figure 2: Wheel Profiles of Piggyback Car CP 505012
After 117,773 Miles of Revenue Service Operation

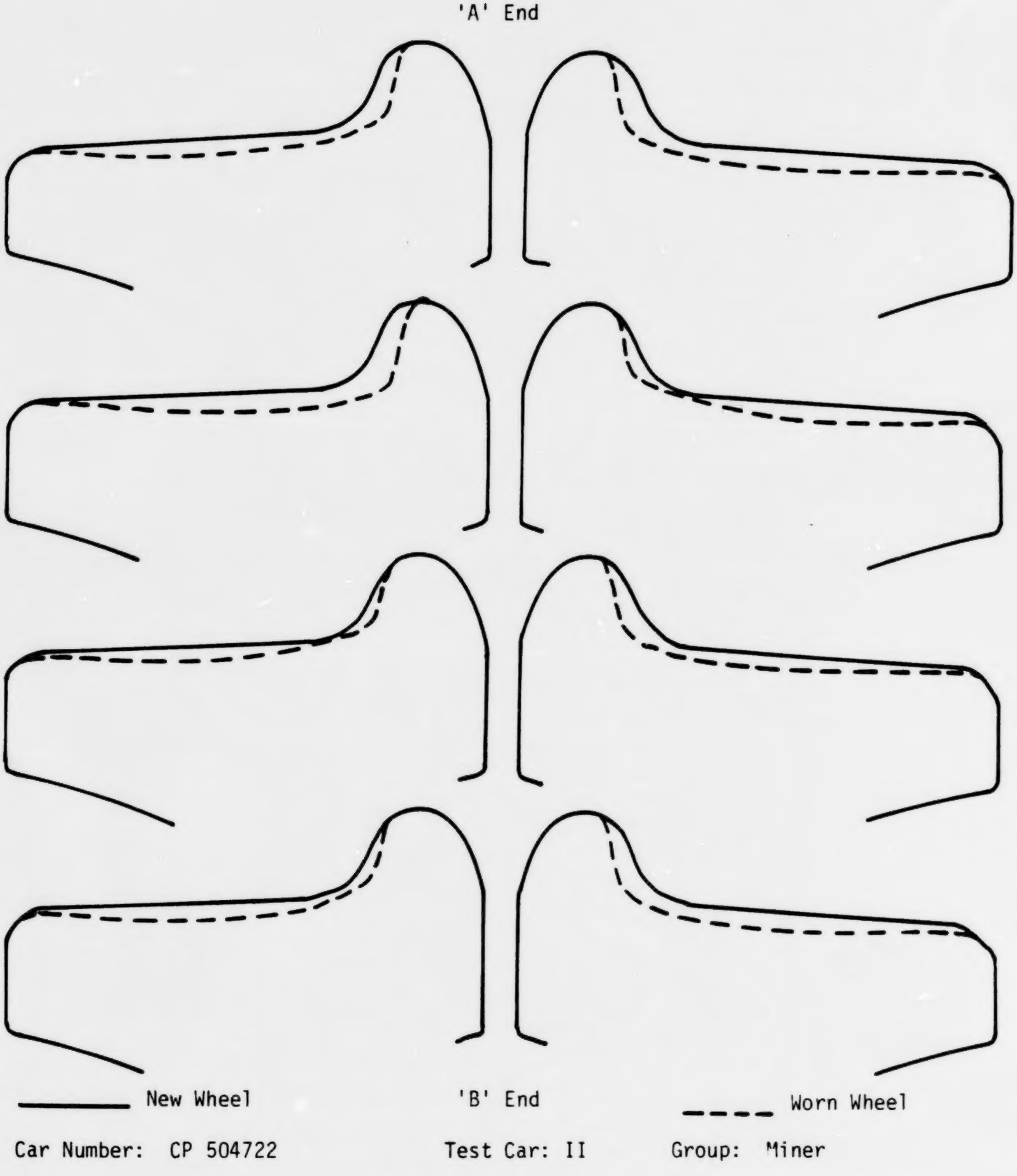
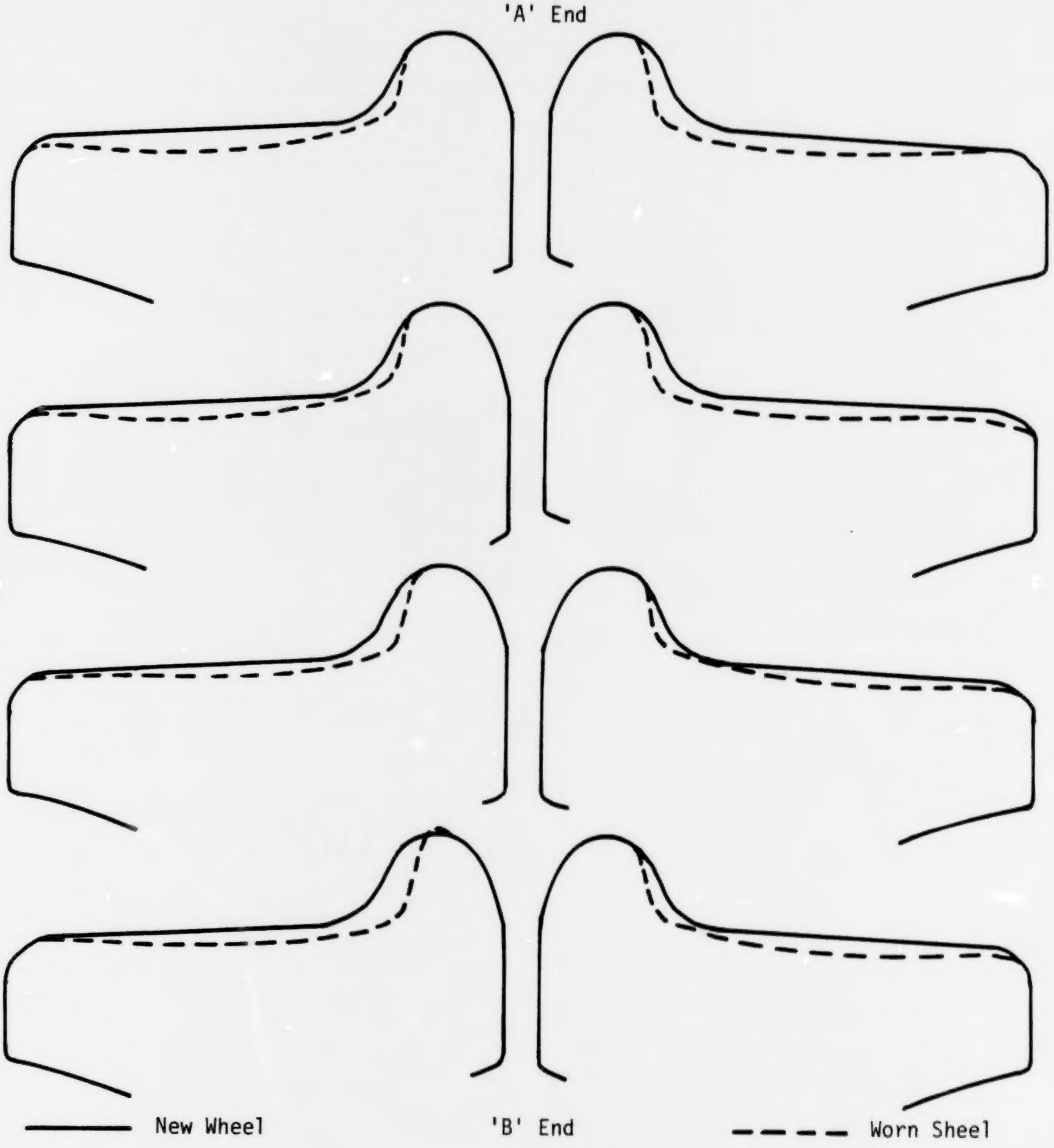
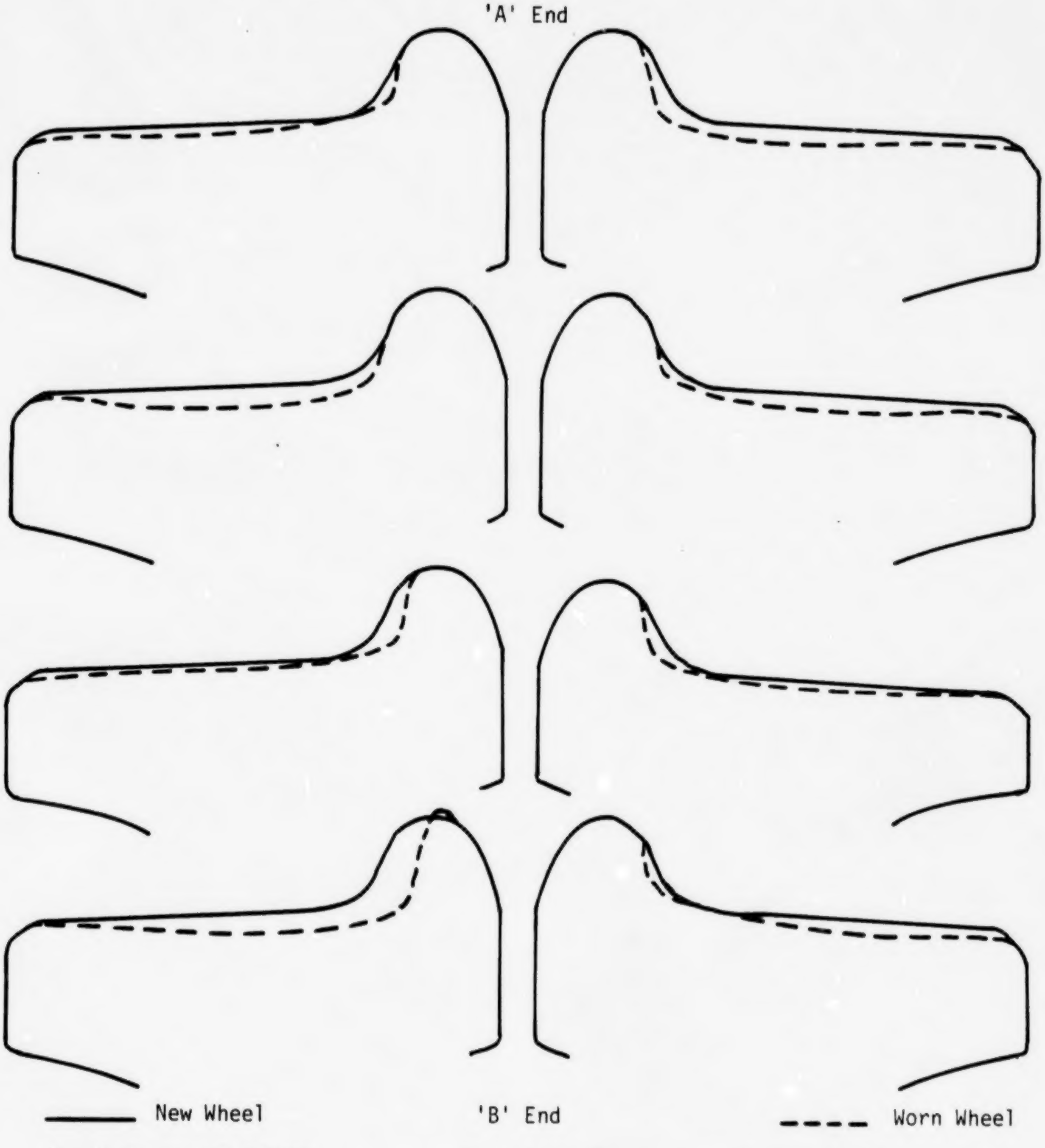

'A' End
New Wheel
'B' End
Worn Wheel
Car Number: CP 504722
Test Car: II
Group: Miner

Figure 3: Wheel Profiles of Piggyback Car CP 504722 After 132,560 Miles of Revenue Service Operation


'A' End
New Wheel
'B' End
Worn Sheel

Car Number: CP 504249 Test Car: 12 Group: Miner

Figure 4: Wheel Profiles of Piggyback Car CP 504249
After 114,503 Miles of Revenue Service Operation


'A' End
New Wheel
'B' End
Worn Wheel

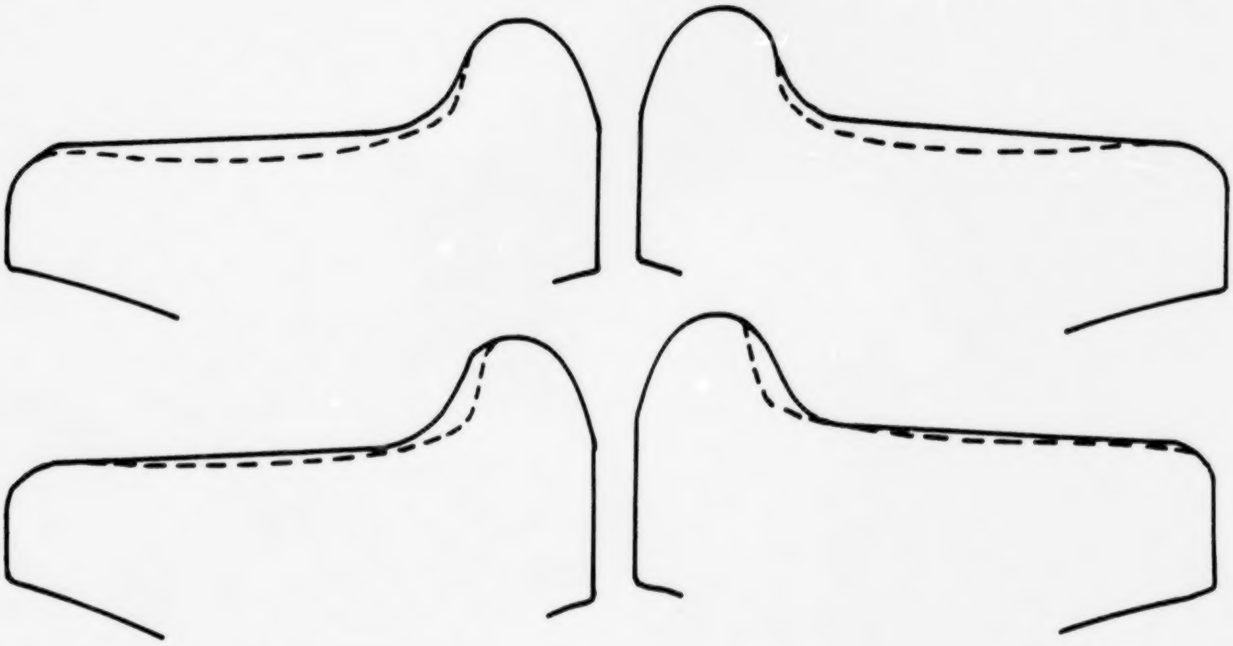
Car Number: CP 504599 Test Car: 21 Group: Stucki

Figure 5: Wheel Profiles of Piggyback Car CP 504599
After 114,090 Miles of Revenue Service Operation

'A' End

L4/R4 Worn Wheel Profiles Not Available

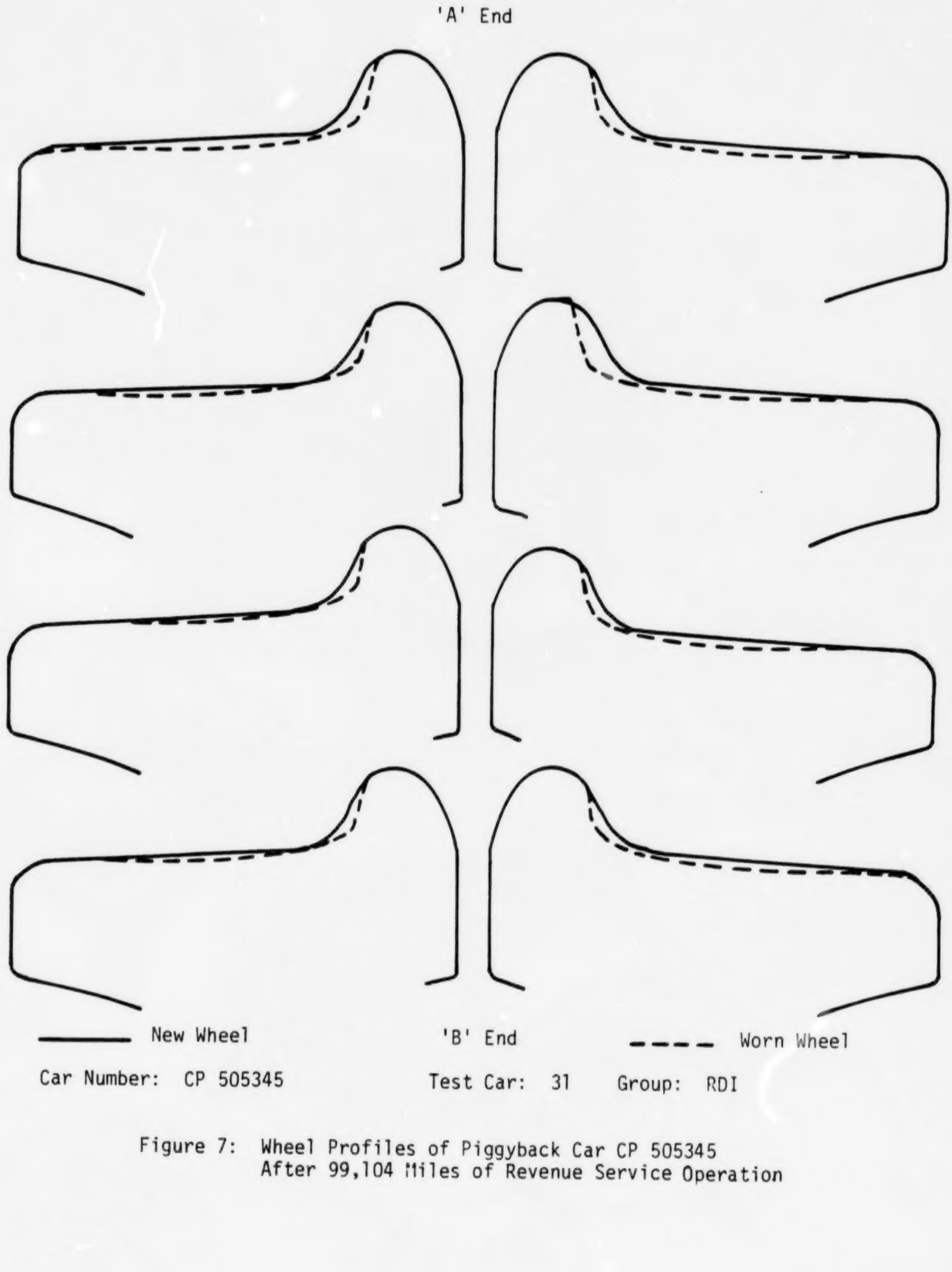
L3/R3 Worn Wheel Profiles Not Available



—— New Wheel   'B' End   ---- Worn Wheel

Car Number: CP 504019   Test Car: 22   Group: Stucki

Figure 6: Wheel Profiles of Piggyback Car CP 504019
After 134,951 Miles of Revenue Service Operation

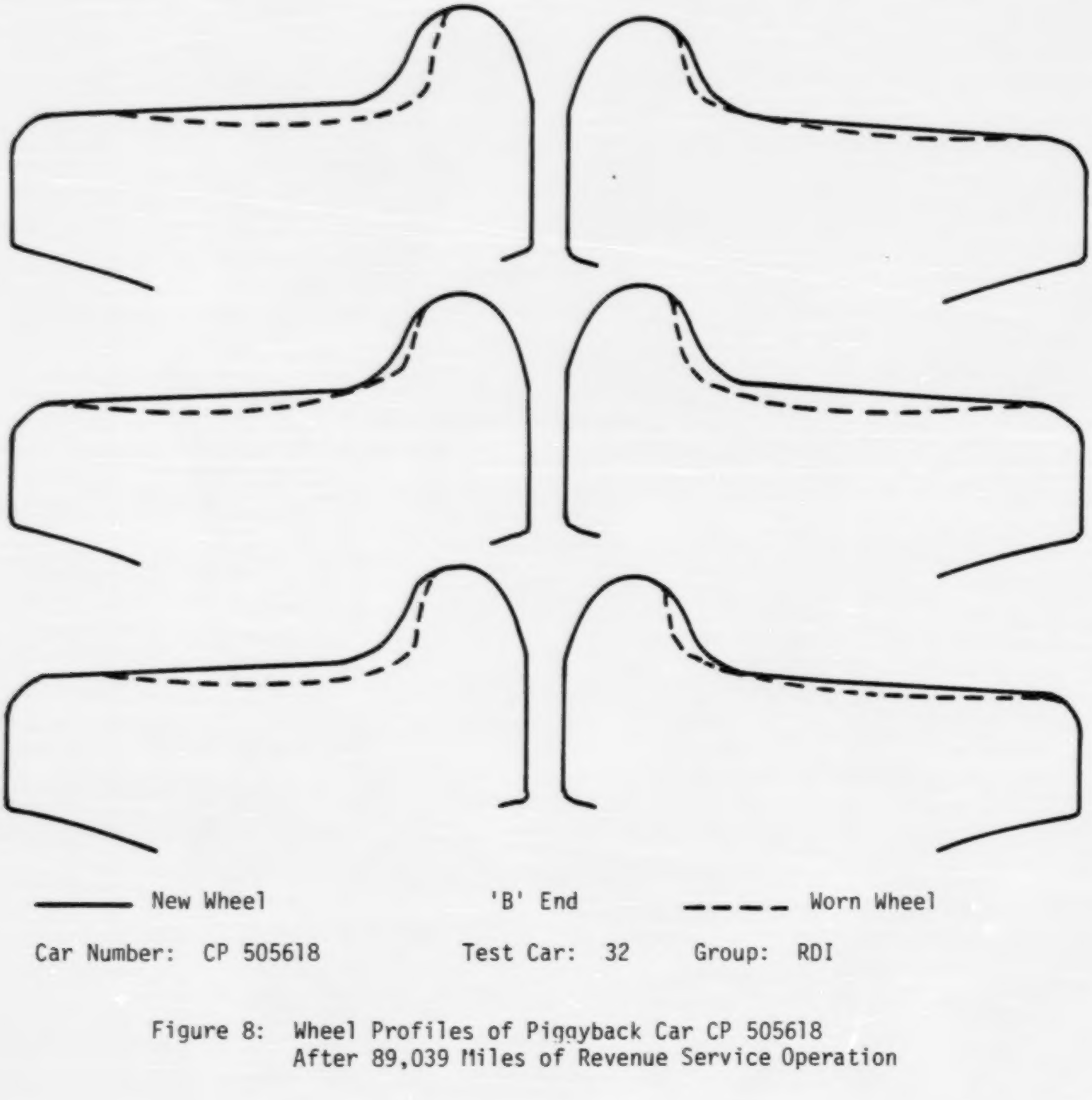

'A' End
New Wheel
'B' End
Worn Wheel

Car Number: CP 505345 Test Car: 31 Group: RDI

Figure 7: Wheel Profiles of Piggyback Car CP 505345
After 99,104 Miles of Revenue Service Operation

'A' End

L4/R4 Worn Wheel Profiles Not Available



—— New Wheel 'B' End - - - - Worn Wheel

Car Number: CP 505618 Test Car: 32 Group: RDI

Figure 8: Wheel Profiles of Piggyback Car CP 505618
After 89,039 Miles of Revenue Service Operation

Canadian
Pacific

Figure 9: Piggyback Car CP 504019 Stripped of its Trucks During Truck Tear Down Inspection at CP Rail's Angus Shops

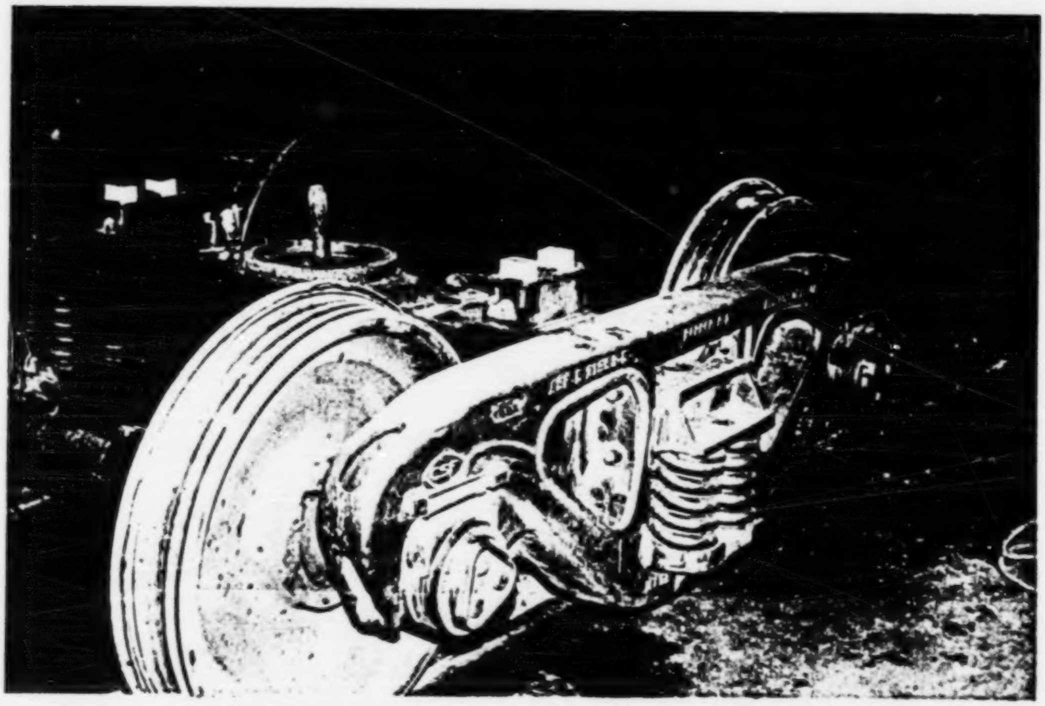


Figure 10: 'B' End Truck of Car CP 504019 Equipped with New Stucki Constant Contact Side Bearings

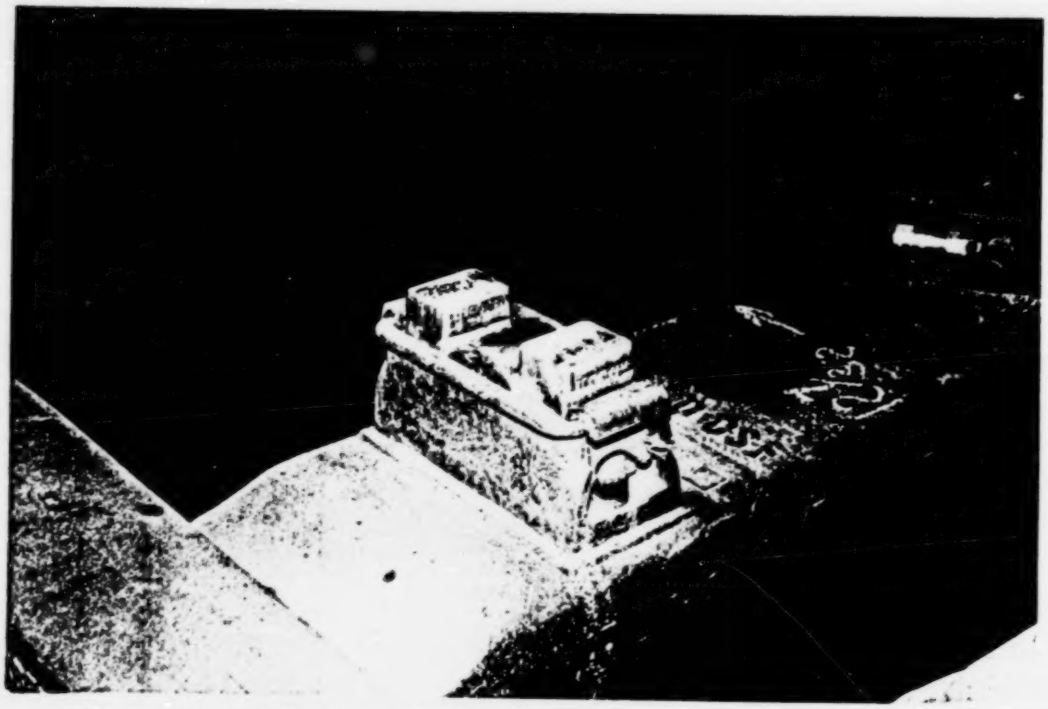


Figure 11: Typical Condition of Stucki Constant Contact Side Bearings After Approximately 200,000 Miles of Revenue Service Operation

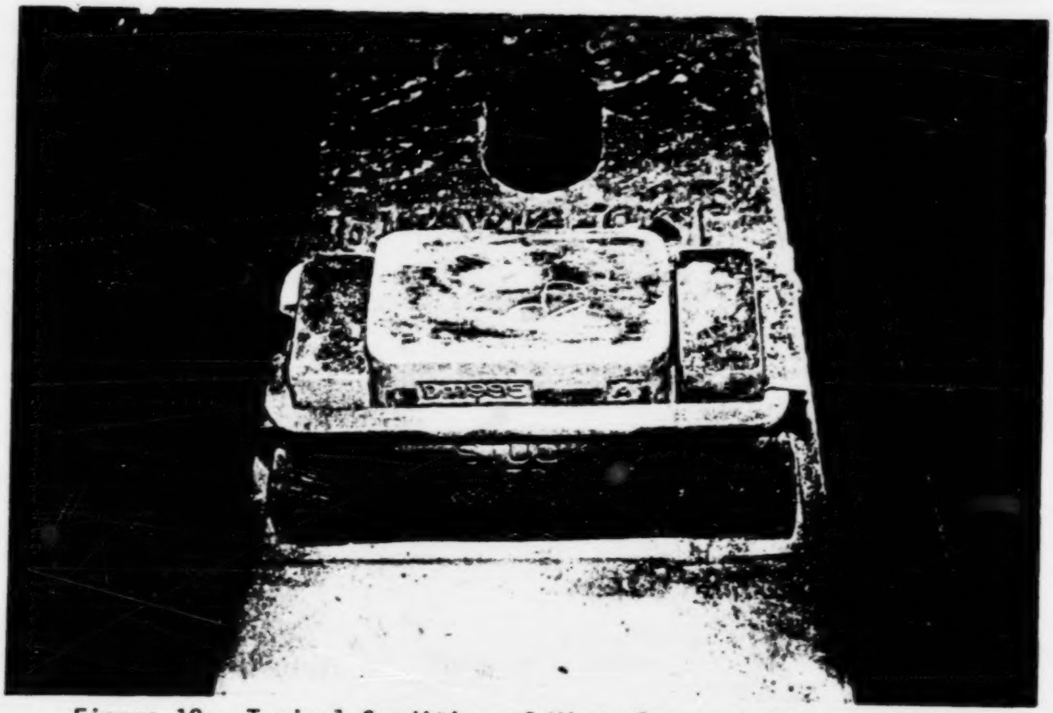


Figure 12: Typical Condition of Miner Constant Contact Side Bearings After Approximately 200,000 Miles of Revenue Service Operation

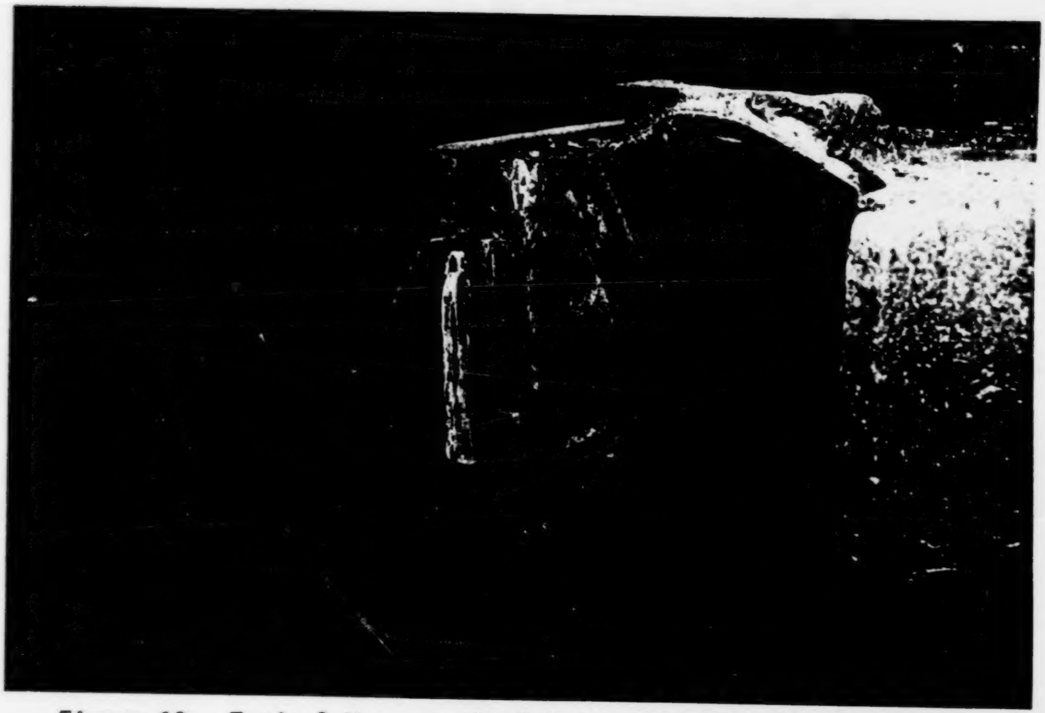


Figure 13: Typical Wear on the Bolster Gib of Trucks Equipped with Constant Contact Side Bearings

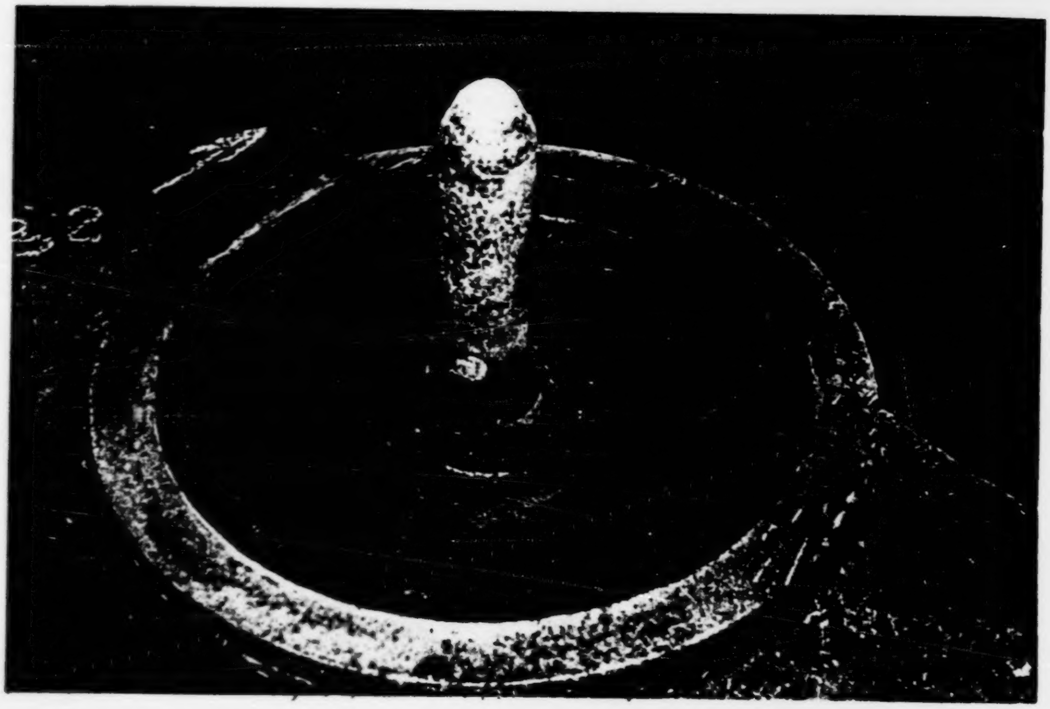


Figure 14: Typical Wear on the Truck Bolster Bowl of Trucks Equipped with Constant Contact Side Bearings

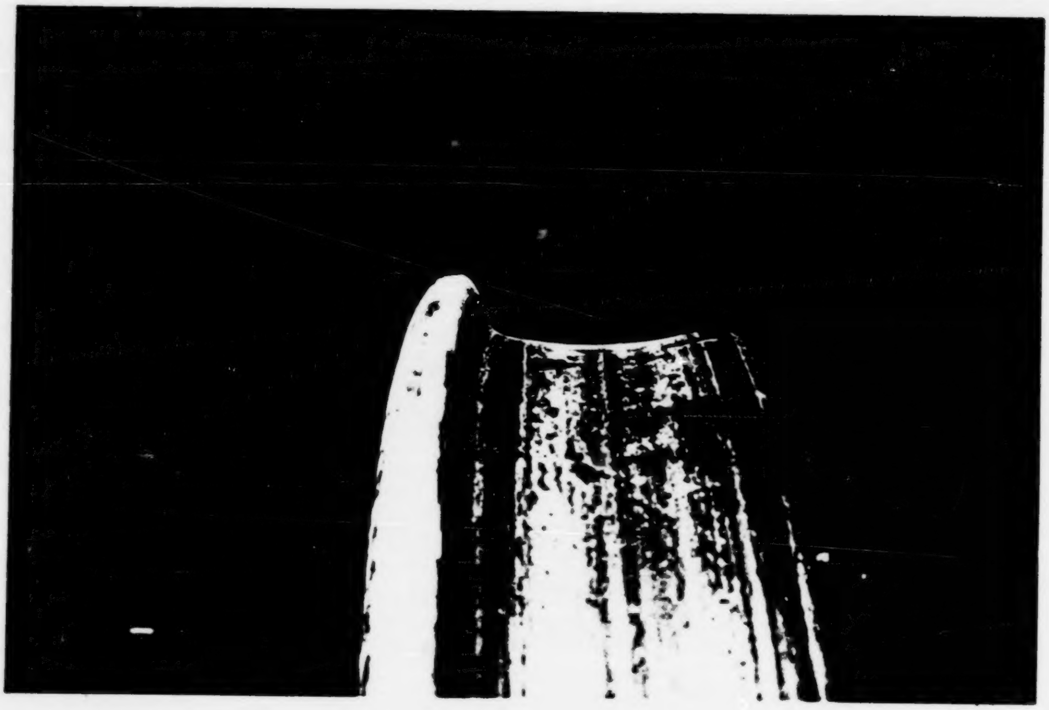
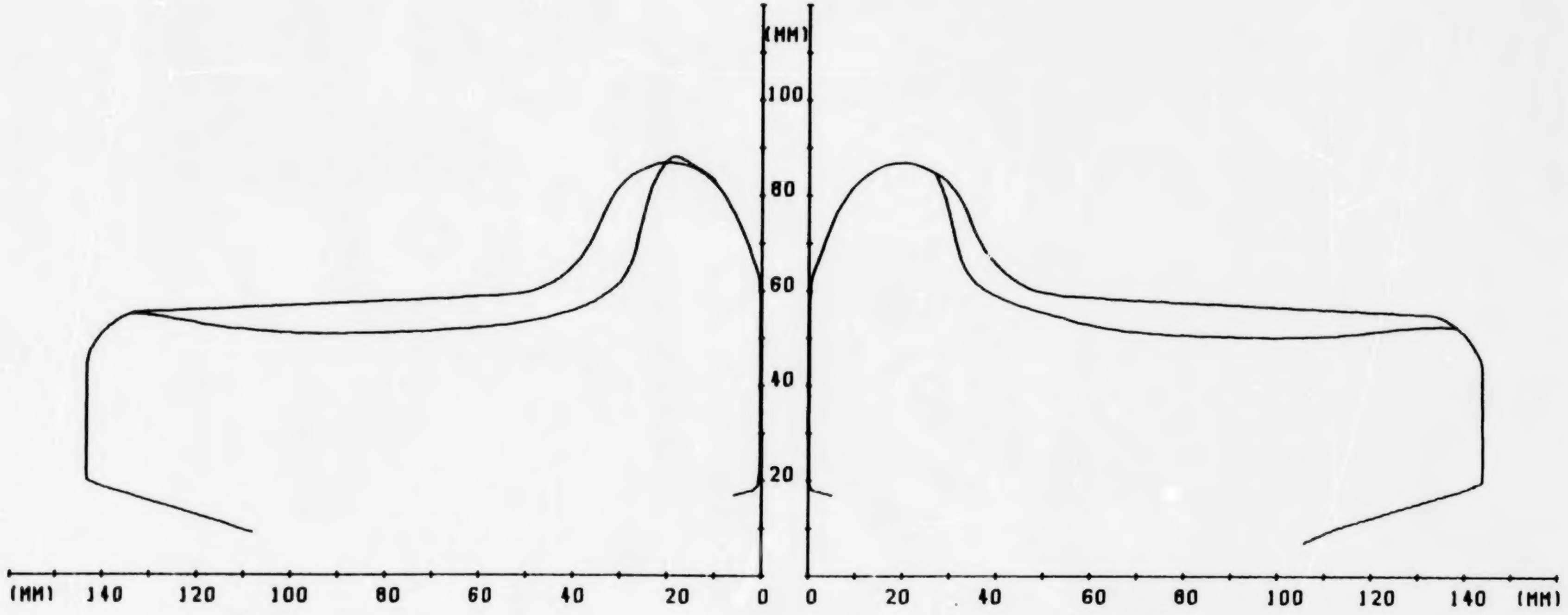


Figure 15: Actual Worn Wheel Profile Showing Typical Wear Experienced by Wheels of Car CP 504249 Equipped with Miner Constant Contact Side Bearings After 207,000 Miles of Service

APPENDIX A

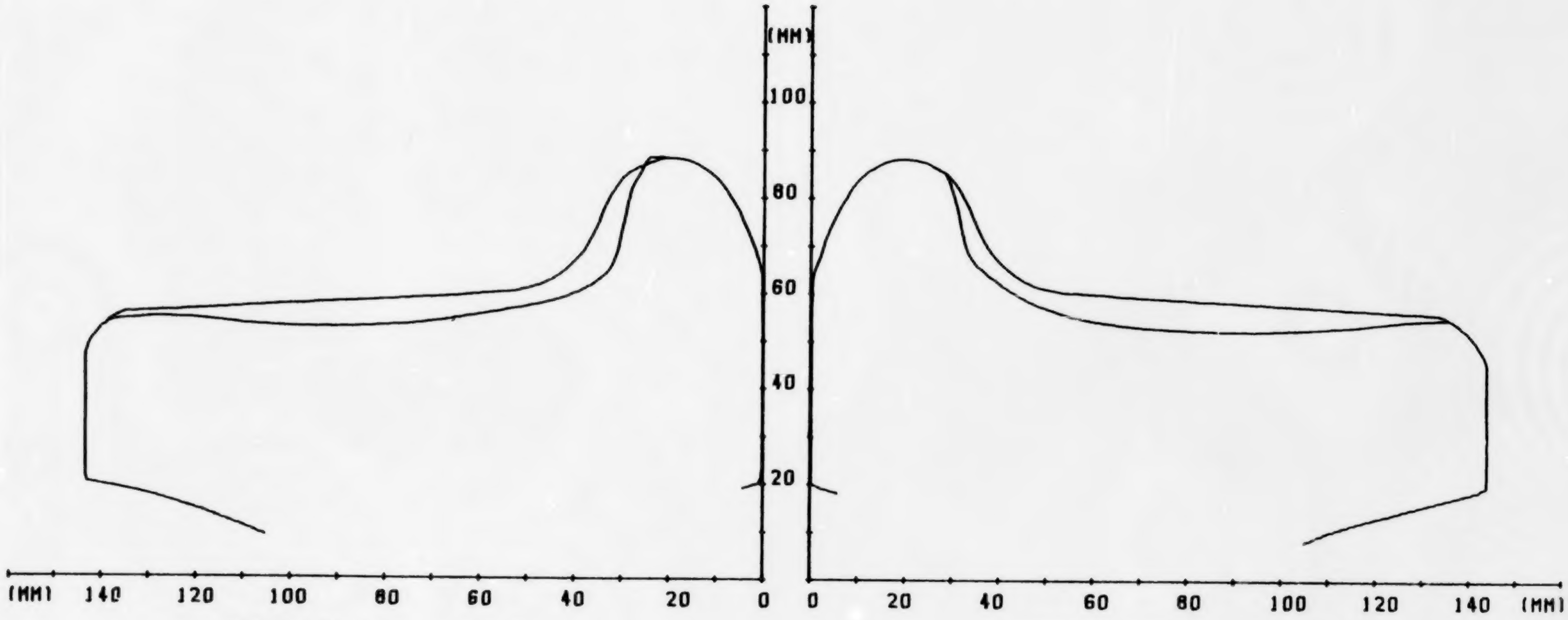
WHEEL PROFILES AFTER 200,000 REVENUE MILES



TREAD WEAR: 6.7 MM
FLANGE WEAR: 10.4 MM
TREAD AREA WEAR: 517.9 SQ. MM
FLANGE AREA WEAR: 243.1 SQ. MM

TREAD WEAR: 6.7 MM
FLANGE WEAR: 5.3 MM
TREAD AREA WEAR: 503.6 SQ. MM
FLANGE AREA WEAR: 103.2 SQ. MM

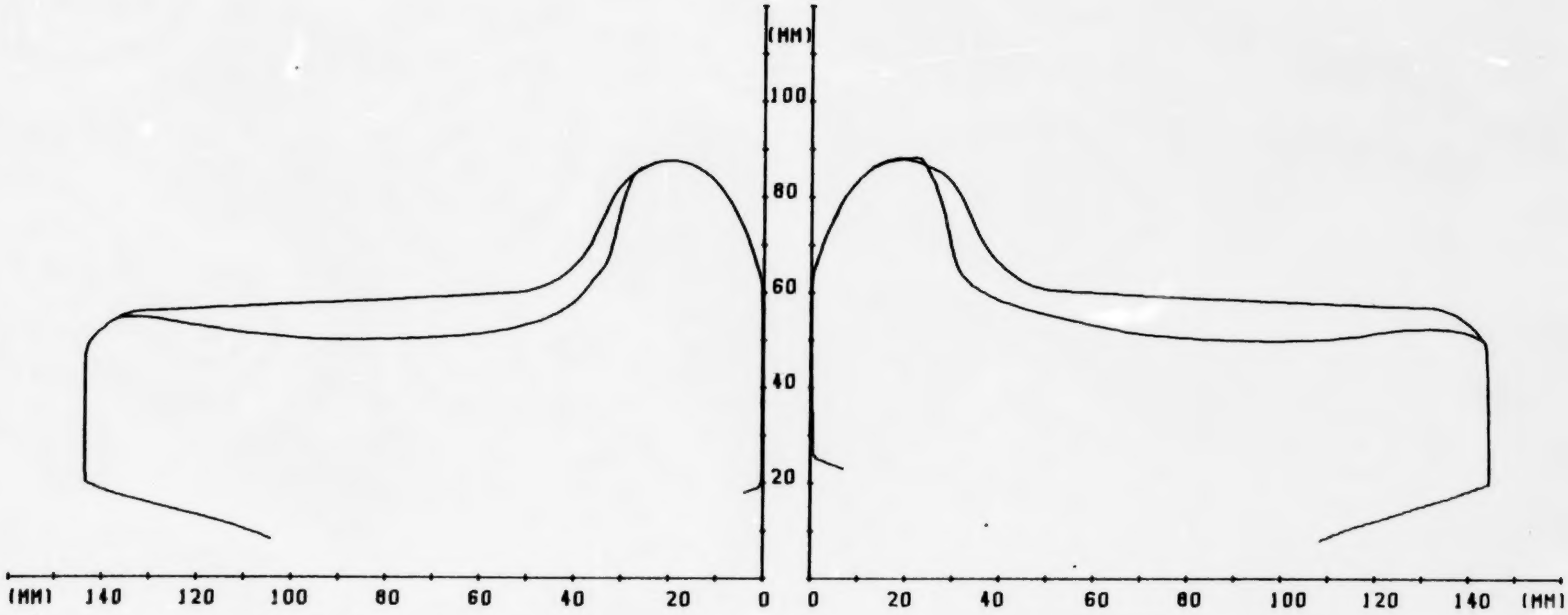
FIGURE A1: L1/R1 Worn Wheel Profiles of Piggyback Car CP 504249 After 191,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)



TREAD WEAR: 5.3 MM
FLANGE WEAR: 6.8 MM
TREAD AREA WEAR: 384.5 SQ. MM
FLANGE AREA WEAR: 137.6 SQ. MM

TREAD WEAR: 6.2 MM
FLANGE WEAR: 4.4 MM
TREAD AREA WEAR: 429.8 SQ. MM
FLANGE AREA WEAR: 66.2 SQ. MM

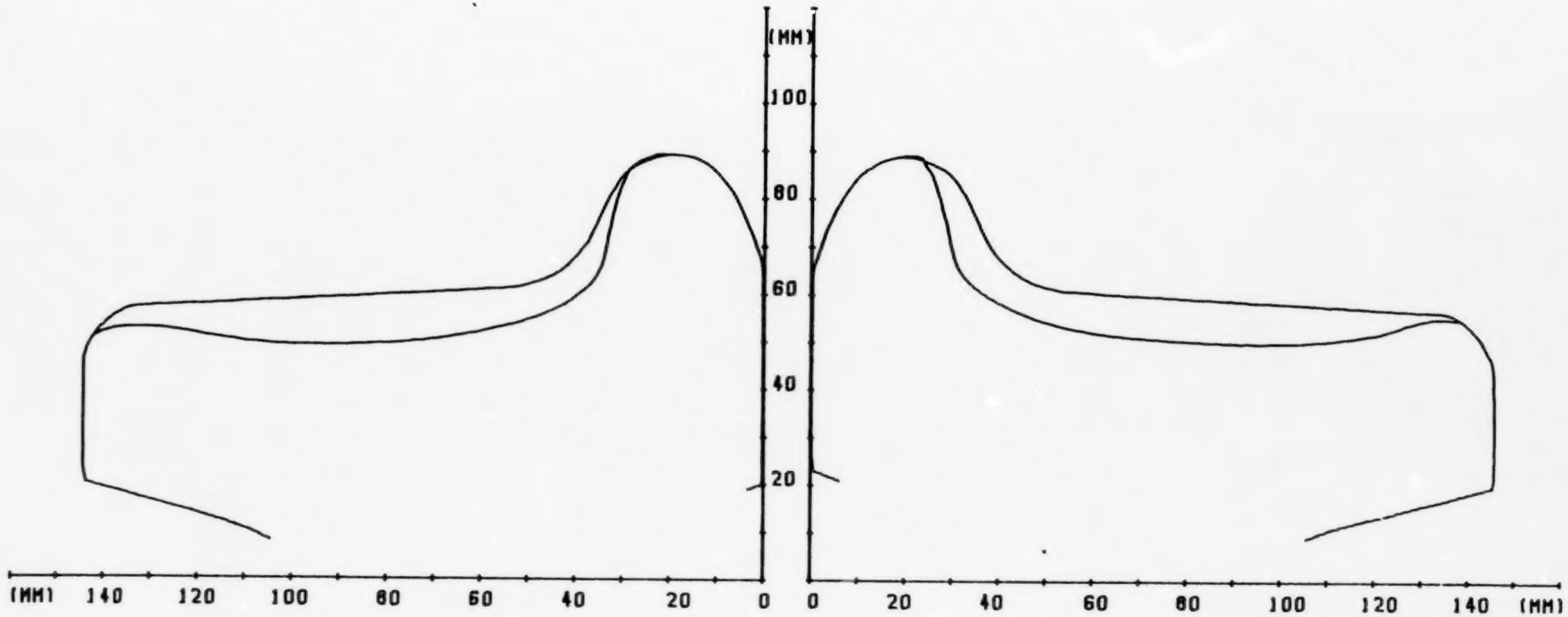
FIGURE A2: L2/R2 Worn Wheel Profiles of Piggyback Car CP 504249 After 191,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)



TREAD WEAR: 8.6 MM
FLANGE WEAR: 4.7 MM
TREAD AREA WEAR: 617.6 SQ. MM
FLANGE AREA WEAR: 91.3 SQ. MM

TREAD WEAR: 8.1 MM
FLANGE WEAR: 6.9 MM
TREAD AREA WEAR: 678.9 SQ. MM
FLANGE AREA WEAR: 144.7 SQ. MM

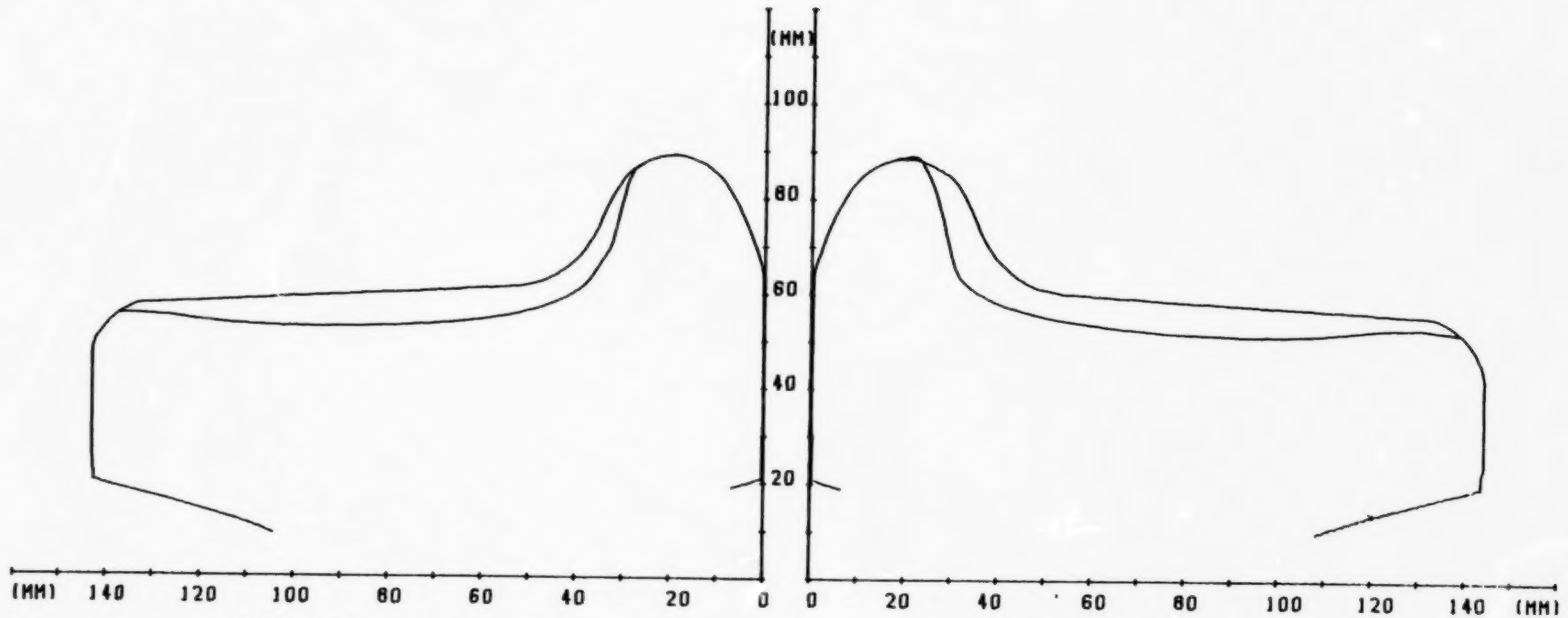
FIGURE A3: L3/R3 Worn Wheel Profiles of Piggyback Car CP 504249 After 191,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)



TREAD WEAR: 9.9 MM
FLANGE WEAR: 4.1 MM
TREAD AREA WEAR: 794.6 SQ. MM
FLANGE AREA WEAR: 86.7 SQ. MM

TREAD WEAR: 8.9 MM
FLANGE WEAR: 8.1 MM
TREAD AREA WEAR: 695.9 SQ. MM
FLANGE AREA WEAR: 174.8 SQ. MM

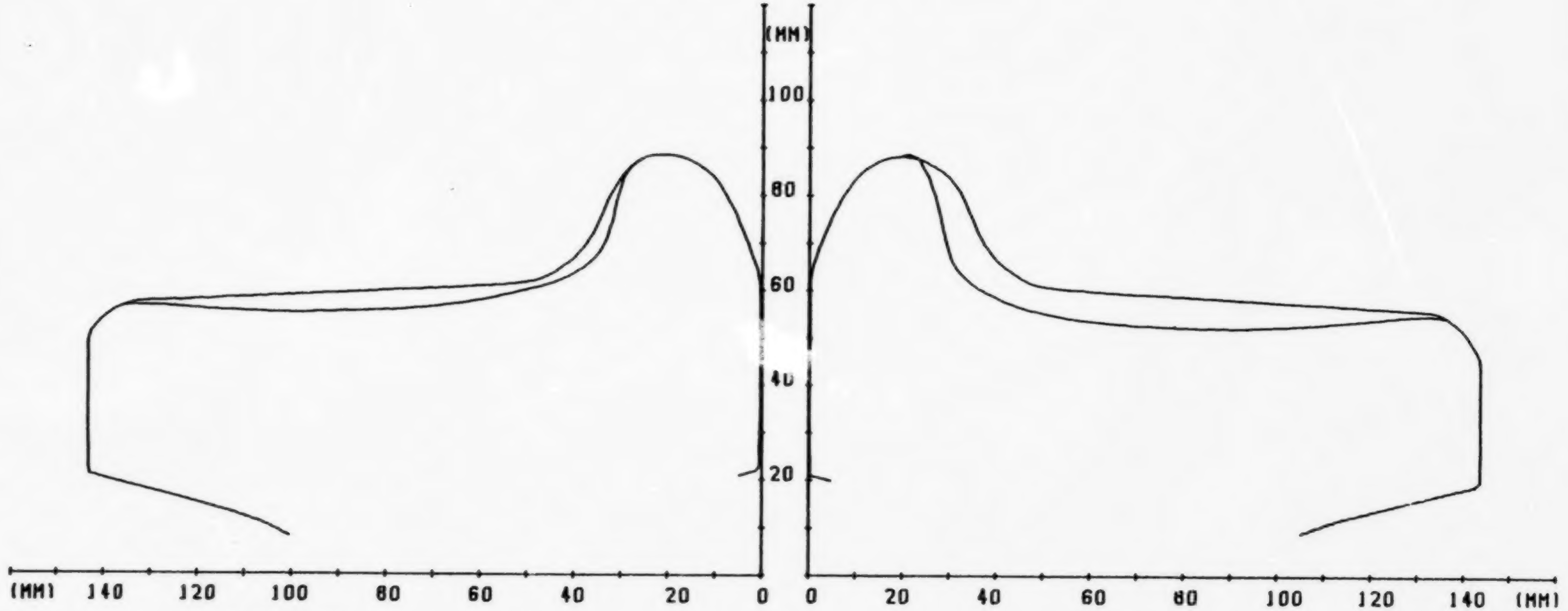
FIGURE A4: L4/R4 Worn Wheel Profiles of Piggyback Car CP 504249 After 191,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)



TREAD WEAR: 6.8 MM
FLANGE WEAR: 4.7 MM
TREAD AREA WEAR: 539.3 SQ. MM
FLANGE AREA WEAR: 82.1 SQ. MM

TREAD WEAR: 6.7 MM
FLANGE WEAR: 8.3 MM
TREAD AREA WEAR: 520.8 SQ. MM
FLANGE AREA WEAR: 164.0 SQ. MM

FIGURE A5: L1/R1 Worn Wheel Profiles of Piggyback Car CP 504722 After 207,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)



TREAD WEAR: 4.0 MM
FLANGE WEAR: 3.5 MM
TREAD AREA WEAR: 272.5 SQ. MM
FLANGE AREA WEAR: 54.2 SQ. MM

TREAD WEAR: 6.4 MM
FLANGE WEAR: 8.0 MM
TREAD AREA WEAR: 458.4 SQ. MM
FLANGE AREA WEAR: 180.9 SQ. MM

FIGURE A6: L2/R2 Worn Wheel Profiles of Piggyback Car CP 504722 After 207,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)

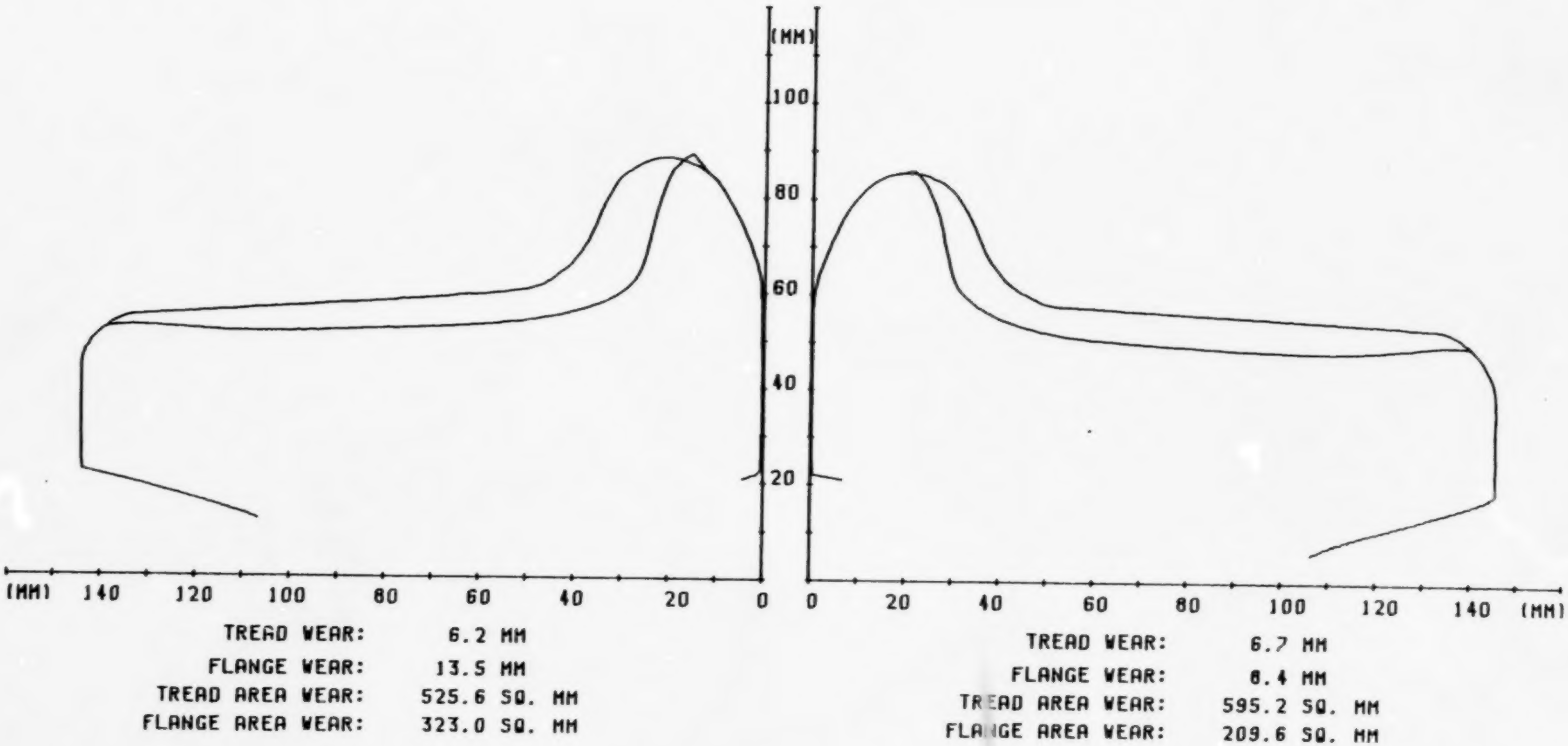


FIGURE A7: L4/R4 Worn Wheel Profiles of Piggyback Car CP 504722 After 207,000 Miles of Revenue Service Operation (Equipped with Miner CCSBs)

Tangent Track Behaviour of Unit Coal Trains
- Preliminary Report -

G.W. Rosval
P.C. Ireland
G. Izbinsky
D. D'Aoust

Research and Development
CP Rail
August, 1985

Summary

Lubrication of the gauge faces of tangent track rails results in a reduction in train resistance according to several studies conducted by the AAR and US railways. For example, tests on the Santa Fe showed that a loaded low side gondola car at 40 mph has 20% less drag on level tangent track for lubricated vs dry conditions. This corresponds to a reduction of about 40 lb. drag force per truck.

The mechanism of this savings is not clear. It may be due, for example, to steady state imperfect wheelset tracking, to the transient responses of the vehicles to track irregularities or to some combination of the two. Whatever the case may be, since it is related to vehicle or track imperfections, the results from one railway do not necessarily apply to another.

A test was devised by the Planning and Research Department of CP Limited, in conjunction with the AAR, to yield information on the tangent track behaviour of laden and empty unit coal trains on CP Rail. Parameters measured were wheelset angles-of-attack and wheel/rail vertical and lateral forces.

A detailed report will be issued jointly by CP and the AAR at a later date. The results reported here are preliminary; experimental values are reported and commented on, but a detailed analysis has not yet been conducted.

Preliminary results are that vehicle departures from perfect tracking are small, dynamic and random. No vehicle measured showed any indication of steady state imperfect tracking, nor did a substantial number of vehicles appear to be responding in a similar fashion at a particular point on the track (they were not responding similarly to some track irregularity at the test site). Except for high speed empty vehicles, which may hunt, it seems as though tangent track behaviour consists of small transitory lateral motions which vary from one vehicle to another and from one point on the track to another.

A sufficient amount of field data is available to allow for a reasonable estimate of fuel savings which would be obtained for lubricated vs dry conditions. It is recommended that no further test work be done on CP Rail aimed specifically at tangent track behaviour until a more detailed analysis has been conducted.

Tests on curved track by the AAR has shown that on-board lubrication systems compliment wayside systems on curves in reducing train resistance. Curving behaviour is generally steady state, repeatable and predictable. It is therefore recommended that CP conduct tests with on-board systems to measure fuel savings possible on curved territory such as is found on the Pacific Region.

SOMMAIRE

La série d'études lancées par l'Association of American Railroads (AAR) et par les chemins de fers aux Etats-Unis a mis en évidence la réduction dans la résistance à l'avancement procurée par la lubrification des faces intérieures des voies en alignement. Ainsi, les essais tenus à Santa Fe ont montré qu'un wagon tombereau chargé, roulant à 40 mi/h sur une voie en alignement en pente, affiche 20 p. 100 moins de traînée en régime lubrifié qu'en régime sec, ce qui correspond à quelque 40 lb de traction de moins, par wagon.

Le phénomène en cause n'a pas encore été tout à fait élucidé. Il serait peut-être dû soit à des défauts de contact roue-rail permanents, soit aux movements de réponse transitoire des wagons aux défauts de voie, soit à une combinaison des deux. Quelle qu'en soit la raison exacte, les résultats ne sont pas forcément transférables d'un cas à un autre, étant donné que les défauts en question sont propres au matériel ou à la voie.

Le Service de planification et de recherche de CP Ltée et l'AAR ont mis conjointement au point une méthode visant à élucider le comportement des trains charbonniers de CP Rail roulant sur des voies en alignement. Les paramètres pris en compte on été l'angle d'inscription et l'interaction dynamique roue-rail (efforts verticaux et transversaux).

Le CP et l'AAR comptent publier ultérieurement un compte rendu détaillé sur les essais effectués. Les résultats figurant ici sont préliminaires. Bien que ne s'agissant pas d'une analyse détaillée, les valeurs provisoires fournies font l'objet de commentaires, mais aucune analyse détaillée n'en a été faite.

Les résultats préliminaires montrent que les écarts par rapport à un contact parfait sont faibles, dynamiques et aléatoires. Aucun des matériels examinés n'a mis en évidence des défauts de contact roue-rail permanents et aucun groupe de matériels n'a manifestement affiché un comportement comparable en un point quelconque de la voie (aucun comportement comparable par rapport à un défaut donné de la voie soumise aux essais). Sauf dans le cas des matériels vides roulant à vitesse élevée, que peuvent souffrir du phénomène de lacet, force est de constater un comportement en alignment consistant en des déplacements latéraux transitoires et de faible amplitude, variables d'un wagon à l'autre et d'un point de la voie à un autre.

Des données expérimentales ont été obtenues en quantité suffisante pour permettre d'effectuer une approximation raisonnable des économies de carburant réalisables grâce à la lubrification. Il est recommandé d'arrêter les essais du CP sur les comportements en alignement jusqu'à ce qu'une analyse plus détaillée ait pu être faite.

Les essais conduits par l'AAR sur le comportement dans les courbes ont montré que les systèmes de lubrification de bord ajoutent leur effet à celui des systèmes en bordure de la voie pour réduire la résistance à l'avancement. Le comportement dans les courbes est généralement de type permanent, répétable et prévisible. Par conséquent, il est recommandé que le CP effectue des essais utilisant les systèmes de lubrification de bord dans le but de chiffrer les économies réalisables sur des tracés sinueux, comme ceux qui caractérisent la région du Pacifique qui est très montagneuse.

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1. Introduction

Work done by the AAR and several US railways shows quite convincingly that lubrication applied to the gauge faces of tangent track rails results in fuel savings. On level tangent track, it is generally assumed that train resistance may be represented by the following empirical formula:

$$R = A + BV + CV^2$$

where R is the resistance in, say pounds/ton, and A, B and C depend on the car type and load. Tests on the Santa Fe with a consist of a GP-39-2 locomotive, a test car, eight mill type low side gondolas and a caboose yielded the following tangent track results:

	40 mph Resistance (lb./car)			
	Unlubricated		Lubricated	
	Loaded	Empty	Loaded	Empty
A term	260	70	150	105
BV term	0	0	0	0
CV^2 term	108	192	136	175
Total	368	262	286	280
HP per car	39	28	31	30

Several unexpected values here lead one to suspect that the general form of the empirical formula is not suitable for evaluating the effects of modifications to equipment and track. Even though there are unanswered questions, the 20% power savings for loaded cars with lubricated track warrants further investigation.

A theoretically perfect vehicle travelling on perfect tangent track has negligible resistance of the type which could be reduced by applying lubrication to the gauge faces of the rails. The reported savings are therefore due to imperfections.

Imperfect tracking of wheelsets on tangent track may be steady state, due, for example, to mis-matched side-frames, or dynamic, due, for example, to cross-level variations (transient) or to hunting (continuous, empty cars).

If the fuel savings are a consequence of vehicle or track imperfections, the results from one railway would not necessarily apply to another. A test was therefore designed and conducted by the Planning and Research Department of CP Limited, in conjunction with the AAR, to obtain information on the tangent track behaviour of unit coal trains on CP Rail.

2. Measurement Systems

The parameters of primary interest here are the longitudinal forces existing (perhaps) between the wheel and rail on tangent track. Unfortunately these cannot be measured for a large number of wheels, however, the extent to which a wheelset is tracking imperfectly can be directly measured and, if desired, longitudinal forces could be inferred under some circumstances.

The Planning and Research Department routinely evaluates the curving behaviour of various truck types by measuring wheelset angles-of-attack with respect to the curve radial line, and wheel/rail vertical and lateral forces. These same parameters were measured for regular traffic on tangent track.

Detailed descriptions of the measurement systems will be included in the final report. They are briefly described here.

Angle-of-Attack: The centerline of the track was established over a distance of 100 feet as being half-way between the gauge faces of the rails. A theodolite accurate to 20 seconds was aligned with the tangent line, and then rotated 90°. The angle-of-attack systems were then aligned with the theodolite. The systems consist of infrared emmitters and detectors, with one beam passing over each rail. The beams are colinear and at 90° to the tangent, therefore the wheels of a wheelset travelling at an angle to the rails will cut the two beams at slightly different times, which are then converted to an angle. The entire system is estimated, in this application, to be accurate to one minute of angle.

Wheel/Rail Forces: Strain gauges were attached to the rails between the ties to measure the shear forces due to vertical and lateral wheel forces. A hydraulic jack was used for calibration in both directions. The force data has not yet been analyzed and is not included in this report.

The sign conventions for angles-of-attack and wheel/rail forces are shown on Figure 1.

3. Test Sites and Trains

Two test sites were selected, at mileages 51.4 and 54.0 on the Cascade Subdivision of the Pacific Region. Mileage 51.4 is on tangent track with 132 lb. rails and wood ties, 100 feet west of the end of a spiral from a 3° left hand curve, and 180 feet east of a switch. Mileage 54.0, on 132 lb. rail with wood ties, is on a long section of tangent track, with the nearest curve to the east being 2 miles away, and to the west, 4 miles.

At each site, three stations were set up. They were located, travelling westward, at 0 ft., 25 ft. and 60 ft. from the beginning of each site. They are denoted S1, S2 and S3. All angles-of-attack and wheel/rail forces were measured simultaneously at each station. The two test sites were done separately.

At each test site, measurements were obtained during the passage of two laden (westbound) and two empty (eastbound) unit coal trains. One additional laden coal train was measured at mileage 51.4.

In this preliminary report, only the data obtained at mileage 54.0 with the angle-of-attack systems will be presented. Descriptions of the trains are:

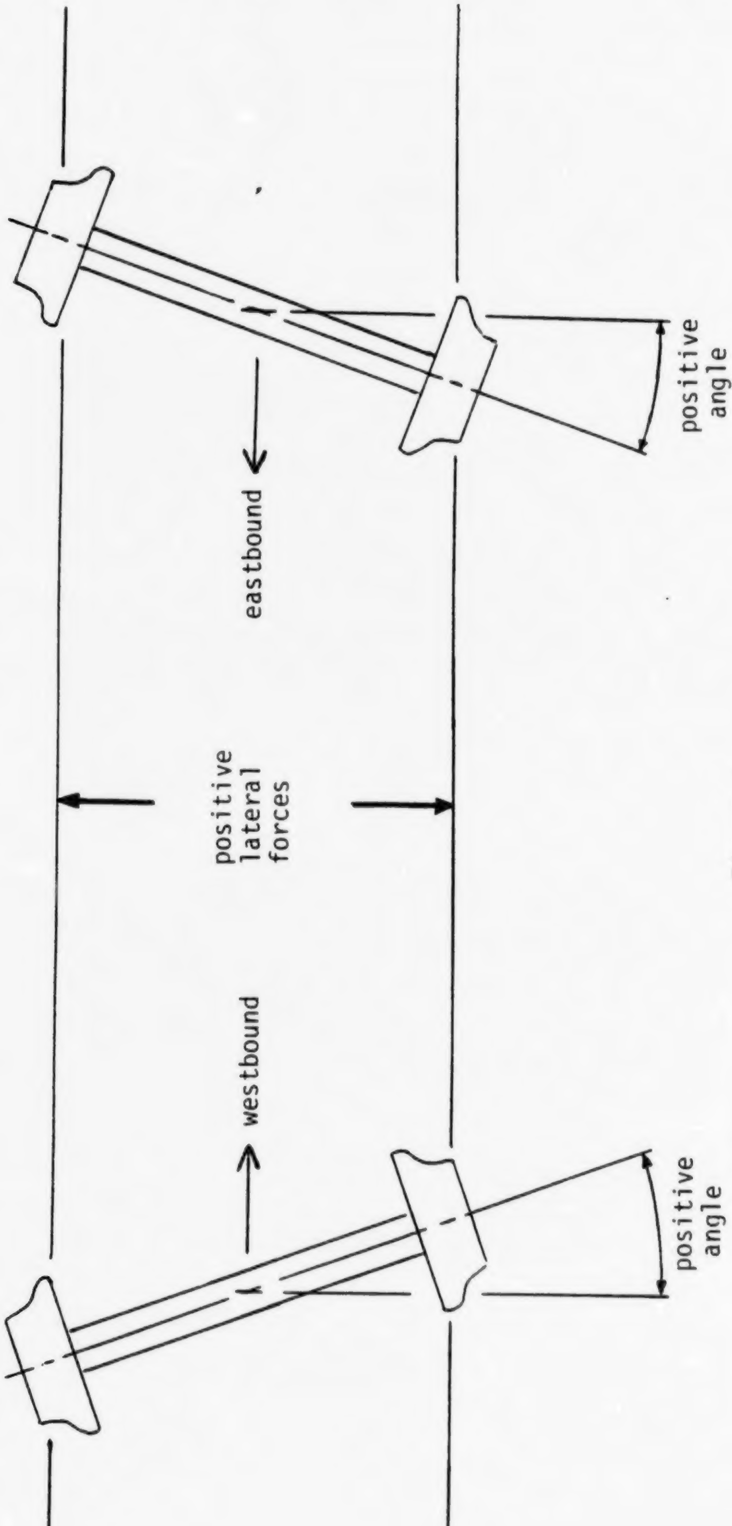

positive angle
eastbound
positive lateral forces
westbound
positive angle

Figure 1

Sign Conventions For Angle-of-Attack and Wheel/Rail Lateral Forces

Designation	Laden/Empty	Number of Coal Cars	Train No./ID	Speed Initial/Final (mph)
L1	Laden	111	803 239 16/X-2	40/39
L2	"	111	823 06 16/Yellow	41/41
E1	Empty	111	826 006 19/Yellow	51/43
E2	"	111	824 005 19/Maroon	35/32

4. Data Analysis

A statistical presentation of the data is given in Table 1. The parameters shown here are calculated after excluding outlyers, where outlyers are defined as those occurrences different from the mean of the original sample by more than two standard deviations. This abnormal 5% (approximately) of the sample have been excluded from this table since they should be treated on an individual basis.

Table 1 shows that both loaded trains and the slower empty train behaved similarly. The faster empty train had a much wider distribution of angles. This is likely due to observed steady hunting of many cars on this train.

Table 1

Train	Mean of Angles			Standard Deviations			Correlations		
	S1	S2	S3	S1	S2	S3	S1-S2	S1-S3	S2-S3
L1	-.3	-.5	-.1	1.7	1.4	1.4	.04	.06	.29
L2	-.2	-.5	-.2	1.8	1.4	1.4	.14	.09	.26
E1	1.2	2.0	-1.4	2.4	2.5	3.0	-.23	.21	.23
E2	.8	2.1	-1.0	1.4	1.5	2.1	-.10	.28	.15

Since three stations, S1, S2 and S3 were set up at distances of 0, 25 and 60 feet, it is possible to evaluate whether or not the vehicle behaviour was steady state. Correlations on a wheelset by wheelset basis were done among the three stations. For example, for train L1, the correlation between the angles at S1 and S2 is only 0.04, indicating that, in general, the angle of a particular wheelset at S2 is quite unrelated to the angle that the wheelset had at S1. The wheelset behaviour is not steady state for any trains presented here, since the correlations are all very low.

The entire distributions including outlyers, for trains L1 and E1 are shown on Figures 2 and 3. Also included are results from a previous test by the Planning and Research Department showing the angles of leading wheelsets on laden coal cars on 2° and 7° curves. These are included to indicate the relative magnitudes of the tangent track data.

As previously stated, the outlyers should be treated on an individual basis. This was done by identifying the cars containing an axle with a high angle and plotting the angles of all four axles as they pass each station. Several of these are shown on Figure 4. As an example, consider the sixteenth car of train E1. As this car passed station S1 its four axles showed angles of 3, -4, -8 and 31 minutes. By the time this car passed station S3, 60 feet away, the angles of the same four axles were -19, 10, -8 and -19 minutes. In some cases, intermediate values, at S2, are also shown.

The method of presentation on Figure 4 would clearly show a pattern if one existed. In addition to those shown, many other vehicles were plotted in this manner. No outlyer showed any steady state imperfect tracking.

5. Conclusions

The wheelsets of unit coal trains on tangent track are not perfectly aligned. The departures from perfect tracking are dynamic, random and generally small.

Steady state imperfect tracking was not observed. This suggests that truck anomolies such as wheel diameter variations, stuck C-PEP etc., if they exist, do not cause the trucks to travel skewed on tangent track.

The dynamic behaviour was not repeatable, that is, when viewed from a point on the track, there was no similarity in angles from one car to another. If the dynamic behaviour was caused solely by track imperfections, each vehicle would be affected similarly.

Figure 2

Angle-of-Attack Distribution For a Loaded Coal Train (L1)

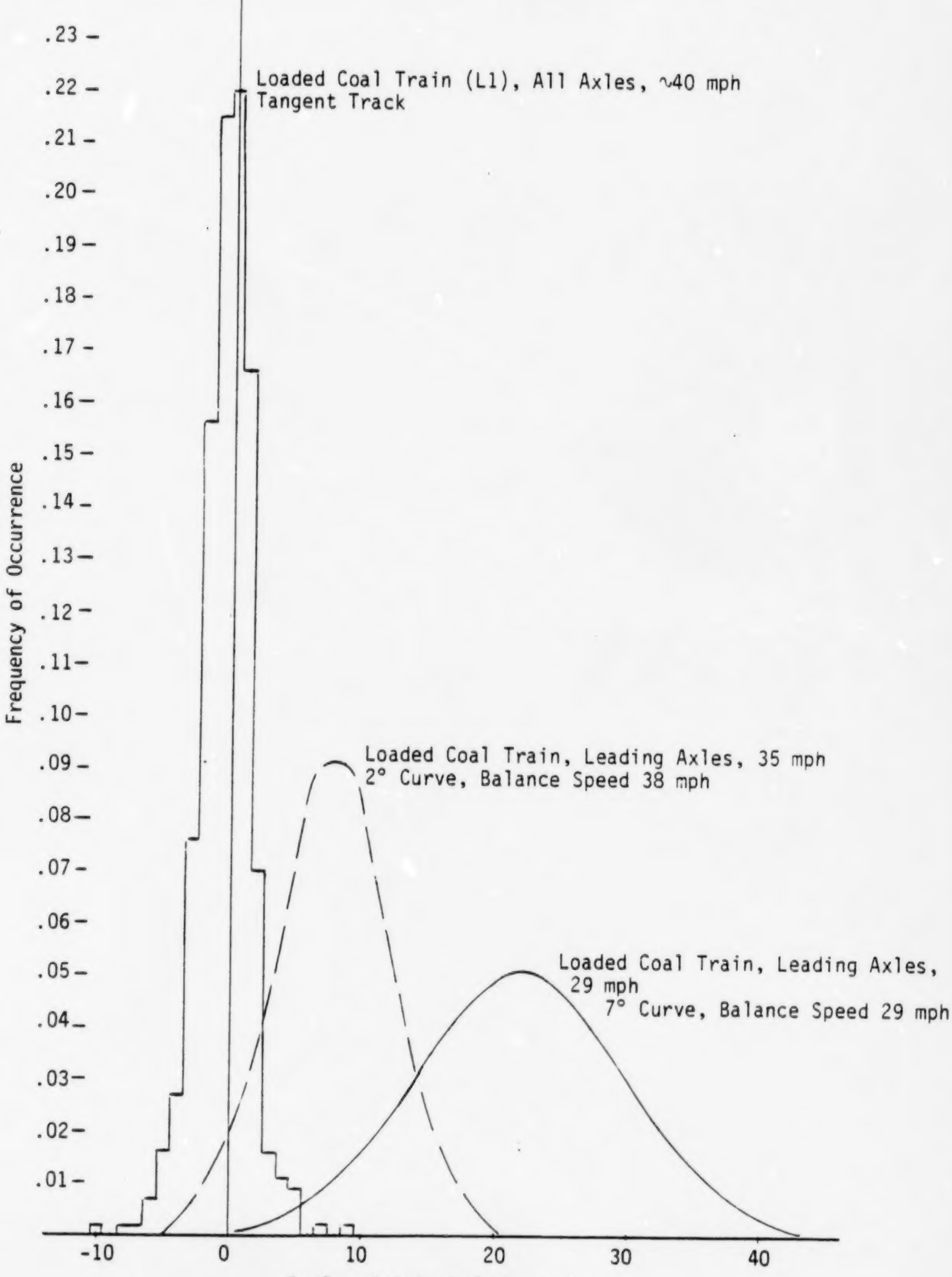
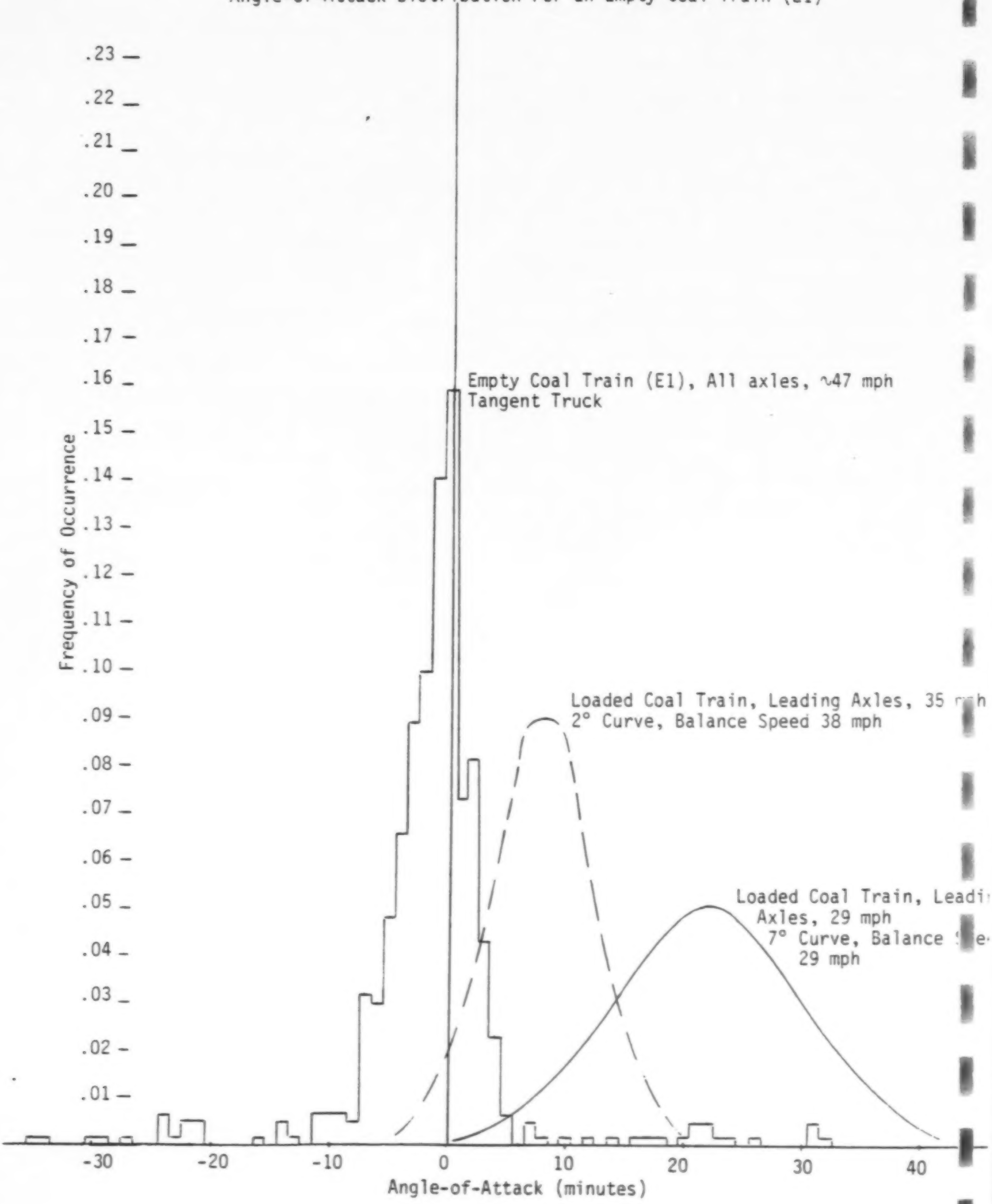


Figure 3

Angle-of-Attack Distribution For an Empty Coal Train (E1)



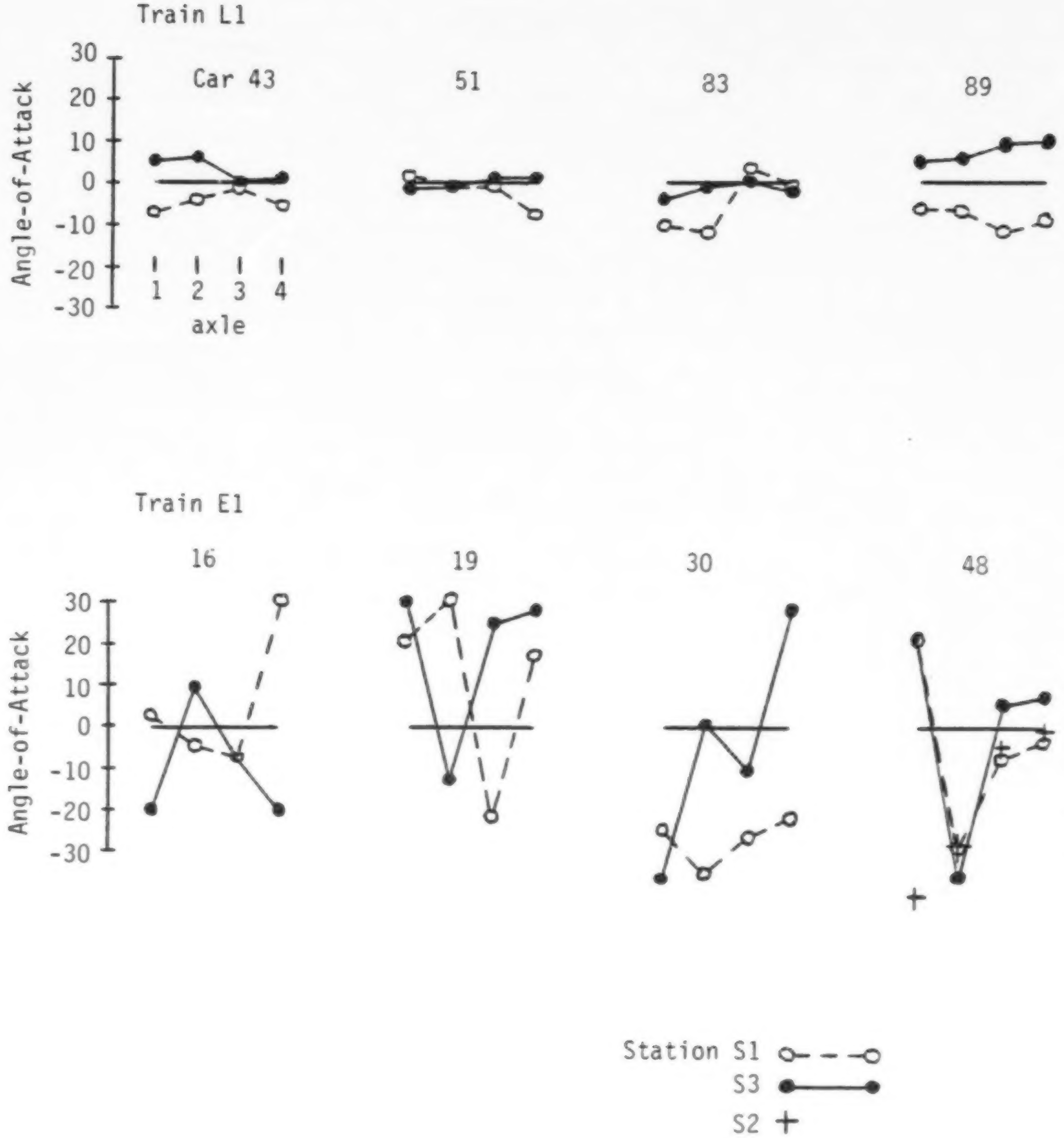


Figure 4

Angles-of-Attack By Car and Axle For Selected Outlyers

The wheelset angles, although small, were easily measurable. The distributions were compared graphically with those from 2° to 7° curves to indicate their relative magnitudes.

There is a certain amount of increased train resistance due to the observed small, random, dynamic wheelset motions. If a lubricant was applied to the gauge faces of the rails (and perhaps inadvertently slightly higher to the gauge corners and inner portions of the heads) train resistance would be reduced. This is attributable to two effects of the lubrication: (1) longitudinal wheel/rail forces would be less due to a reduced friction coefficient, and (2) the transient responses of wheelsets would die out more quickly.

6. Recommendations

Any further field work directed towards understanding and quantifying fuel savings by tangent track lubrication would require an investigation of minor vehicle and track structure anomolies and how they interact. Enough field data is now available so that fuel savings by tangent track lubrication could be estimated by computer simulations. This direction should be pursued.

Extensive field testing by the Planning and Research Department of the curving behaviour of different vehicles has shown this to be steady state and repeatable. Tests by the AAR and US railways have shown that on-board lubrication systems compliment wayside systems in reducing curving resistance. It is therefore recommended that the emphasis of CP Rail field testing be to quantify the train resistance reduction obtained by rail lubrication with on-board systems on curved territory such as is found on the Pacific Region.

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